From fundamental research to commercialization of forced pulsed waterjet machines – hard road for success

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ABSTRACT

The main emphasis in this paper is on the hardships that one faces in commercializing an invention. The paper gives a brief description of the ***f***orced ***p***ulsed ***w***ater***j***et (FPWJ) technology followed by seemingly daunting obstacles that one must overcome to achieve success.

1 INTRODUCTION

In the present paper I have described my experience of the past 12-years in commercializing the simple internationally patented FPWJ technique for many industrial applications, the current focus being prepping of various surfaces and stripping of hard coatings from aircraft parts. Departing from the conventional jargon of writing papers, I have used the terms "I" and "you" to describe my personal experience. The paper is also meant as an advice to any one who is considering commercializing his/her own invention, assuming that it is his/her ***genuine*** invention. If it is not genuine, you may gain in the short term, in the end, however, ***YOU WILL FAIL (there is enough evidence about this on the internet).*** It is also important to emphasize that the material in this paper is perhaps not new or, may even ***sound absurd***. It may also ***upset or annoy*** some individuals or corporations in the audience or, who may read the paper once it is published. However, the most important point is: "***It is my experience and the hardships that I have endured to commercialize the FPWJ technology.***" Having said that, I sincerely believe that you have something to learn from what I have to say in this paper. Starting with a brief description of FPWJ products, I have described the experiences from the date VLN was revived in January 1998 (incorporated in Canada in 1989).

2 BACKGROUND OF VLN

I started my career on waterjet technology at the National Research Council (NRC) of Canada in 1975. The tasks addressed included research, development and applications of cavitating and pulsed waterjets, including some research on precision cutting with the ultra-high pressure (≥ 207-MPa) waterjets (with and without abrasives). In 1989 due to budget cuts, NRC had decided to terminate the waterjet project. Not interested in taking any other job at NRC, I formed and incorporated VLN. However, at about the same time, a conglomerate of mining companies, called HDRK, had known that I was working on forced cavitating and pulsed waterjet techniques (**1**). Based on this knowledge, HDRK approached NRC to reinstate the waterjet project so that these techniques could be investigated for pre-weakening of hard rocks ahead of continuous mining (tunnel boring) machines. The project was reinstated and during the ensuing 4-years, I worked on these techniques and proved that they were highly promising for mining applications. In 1994,

the mandate of HDRK changed and they terminated the contract. During the next two years there were substantial budget cuts to NRC which, subsequently resulted in the termination of waterjet project in 1997. On January 02, 1998 VLN was reborn.

3 BRIEF DESCRIPTION OF FPWJ TECHNIQUE

3.1 Basics

As FPWJ is not the focus of this paper, only a brief description is given here to highlight some of its exceptional benefits. Extensive details are given in several publications, including patents (**1** to **7**). Also as disclosed in (**1**), the configuration shown in Fig. 1 can also be used for generating forced frequency-controlled cavitating waterjets in submerged and 'in-air' environments, which is not described here. The potential of forced cavitation for deburring, peening and many other interesting applications has been demonstrated to several end-users.

FPWJ is generated by placing a small probe, called microtip, inside the nozzle as depicted in Fig. 1. The microtip is driven by a piezoelectric transducer powered by 20-kHz ultrasonic generator (**2, 3** & **4**). The patterns of the FPWJ thus produced are displayed in Fig. 1(B) and Fig. 1(C). In contrast to the continuous waterjet (CWJ), the efficacy of FPWJ can be controlled by several operating and configurational variables. These are: Operating parameters: pressure (P), orifice diameter (d), traverse speed (V_{tr}), frequency (f), and amplitude (A_m, set on the ultrasonic generator); configurational parameters: distance of the microtip from the exit plane of the orifice ('a') and the geometry of the orifice-microtip assembly. To facilitate well-coordinated operation, a set of plots (graphs), an example of which is depicted in Fig. 2, is normally included in the operating manuals of the FPWJ machines. Although observations applicable to these plots have been reported in the earlier publications (**5**), their importance for practical applications has only been recognized quite recently (**3**). The plot basically shows the effect of 'a' on performance (mass loss) for a given set of operating parameters (P, d and A_m). Obviously, this effect varies as P, d or A_m are changed (**5**). For the sake of illustration, it can be clearly seen that a slight change in the value of 'a' from 5.86 to 7.45-mm, improves the performance almost by a factor of two, without any change in the standoff distance. This change in performance occurs due to the change in the characteristics of the pulses (Fig. 3) as reported in detail by Bai, et al. (**5**). This study has also indicated that the formation of pulses is due to the cyclic growth and collapse of cavitaion bubbles (gaseous or vaporous) in the wake downstream of the microtip. As illustrated in Fig. 4, the dimensions of the wake depend on the magnitudes of 'a', P, d and A_m. The existence of the wake can be clearly seen in Fig. 4 (C), (D) and (E), taken from the old publication (**6**). In other words, these recent observations have confirmed the original hypothesis proposed by Puchala and Vijay (**7**) that cyclic growth and collapse of a cavitation bubble is responsible for the formation of pulses. In other words, the growing-collapsing bubble acts as a valve, momentarily interrupting the flow of water through the nozzle (at the time of writing this paper, further theoretical work on this premise is in progress).

Now referring to Fig. 2, why is this plot important for practical applications? Briefly, this can be explained by examining the three examples illustrated in Figs. 5, 6 and 7 (**3**). Figure 5 shows several tests conducted on removing a multi-layered epoxy coating from a part fabricated from a composite material. This is quite a challenging task as the coating is generally harder than the substrate (it becomes even more challenging if the composite material contains graphite, which swells if water ingresses the substrate). The

data shown in Fig. 2 offer several alternatives to remove the coating without damaging the substrate. For example, if we set 'a' = 7.45, the jet is very powerful at standoff distance of approximately 75-mm. At these conditions, FPWJ will cut the substrate. By merely setting the value of 'a' to 5.86-mm, FPWJ becomes less aggressive and the coating could be removed without damaging the substrate. Other possibilities are: lowering the pressure, increasing the traverse speed or the standoff distance, etc. Figure 6 shows prepping the surfaces (creating aesthetic patterns) of building blocks (generally rocks). In this case, unless appropriate configurational and operating parameters are used, considerable spalling of the surface will occur. Figure 7 shows prepping the surface of wooden floor panels for injecting resins, which is believed to enhance the life of the panels. Since wood is fibrous, once again appropriate conditions must be used so that the fibres do not show up. Therefore, the data in Fig. 2 offer the end-user several alternatives to get the job done efficiently with the desired result.

3.2 Evolution of FPWJ Machines and Systems

The evolution of the FPWJ machines and systems over the past twelve years is shown in Figs. 8 to 15 (see below about "learning from mistakes"). Briefly:

Figure 8: This was the first compact FPWJ machine manufactured to demonstrate the potential of the technique for practical applications. It was rated to operate at a maximum flow rate of 22-litre/min at P = 25-MPa and frequency (f) = 15-20-kHz. Unfortunately, the magnetostrictive transducer located right inside the nozzle did not survive after a few minutes of operation (waterjet technology is quite expensive and therefore reliability is of utmost importance). However, as magnetostrictive transducer has several advantages, work continues to improve its reliability (**2**).

Figure 9: This was the second pre-commercial portable FPWJ machine manufactured under contract from the National Defence of Canada. It is a complete machine consisting of high-pressure pump {P = 41.4-MPa and hydraulic power (h_p) = 16-kW} and ultrasonic generator {Power (P_u) = 1.5-kW} for driving the piezoelectric transducer at 20-kHz. As it was designed for use with the single-orifice nozzle (d = 1.36-mm) only, it had limited applications. Nonetheless, it was quite useful for demonstration to several end-users and for some commercial contract jobs.

Figure 10: This machine was manufactured after a humiliating experience at one of the waterjet conferences (see below about "humiliation"). This machine consists of the same components as the machine described above except the pump was upgraded to deliver 53-litre/min of water at the rated pressure of 103.5-MPa. This machine has been used with single-orifice and multiple-orifice (rotating and non-rotating) nozzles. Although it has not been sold, it has been used for many demonstrations, industrial and government contracts.

Figure 11: This was manufactured after a remark by a contractor in Sweden, "why do you market the complete machine (Fig. 10), when you do not manufacture pumps (listening and learning from end-users)?" Labeled as "RFM (Retrofit Module)", it is simply a pulsed waterjet generator that can be used by the end-user with his pump and other accessories. It is rated to operate up to a maximum pressure of 69-MPa and flow rate of 76-litre/min.

Figure 12: Once again this machine was manufactured after comments by another contractor, "most of the contractors have now 138-MPa pumps; if you just manufacture the 69-MPa RFM, then they cannot have your pulsed waterjet technology (good advice)." This RFM is rated to operate at pressures up to 138-MPa and is our current version for marketing FPWJ technology.

Figure 13: The rotating nozzle assemblies that have been manufactured for use with the FPWJ machines mentioned above are capable of removing a maximum width of

approximately 0.1-m of coating per pass of the nozzle over the part. For many applications, for example, for stripping non-skid epoxy coating from naval decks, this is not enough. The add-on system, called ***TURN*** (***t***win-***u***ltrasonic-***r***otating-***n***ozzles) depicted in Fig. 13, has been manufactured to address this issue. It consists of two rotating ultrasonic nozzle assemblies located inside the drum (lawnmower type). At pressure of the order of 100-MPa, it is capable of removing up to 0.41-m wide coating per pass over the surface to be restored.

Figures 14 & 15: Working with many industrial partners, VLN now has the expertise to integrate and manufacture completely automated systems for the removal of coatings. The system depicted in Figs. 14 and 15 was manufactured and installed for Vector Aerospace in Canada for removing several types of coatings from Pratt & Whitney aircraft engines.

3.3 Learning from Mistakes and Feedback from End-users

One of the challenges that I have encountered as a start-up or, inexperienced entrepreneur, has been to determine the type of machine the end-user wants or, the market for such machines. This is where teamwork with the end-user can be of great benefit. We have discovered that working with an end-user who is willing to share his experience and any new knowledge about the machine he has purchased results in improvement of the reliability and performance of the machine, through joint effort and collaboration. This also provides an excellent opportunity for both parties to share the IP (intellectual property) under specified terms of agreement. Unfortunately, there are end-users who only communicate when there are problems with the machine. One must be cautious with end-users who remain silent despite NDA (nondisclosure agreements) that have been endorsed in good faith to share new knowledge arising from the use of the machines. We have knowledge that certain end-users re-engineer products for use in their own countries, and subsequently attempt to patent what is essentially a stolen intellectual property. With such end-users, faith is only "good" on paper. With the exception of two two-end users with whom we have interacted, others, as stated above, have contributed to the development of the machines depicted in Figs. 11, 12 and 13. This demonstrates that an open and productive relationship with the end-user can lead to a great deal of progress.

4 HARD ROAD AND OTHER CONSIDERATIONS

4.1 Preamble

Prior to reviving VLN, I took some training sessions on "entrepreneurship." Does this help in commercializing a new innovation? The remarks from Stolze (**8**) answers this question: "Even today, when entrepreneurship is in the curriculum at about 500 colleges and universities throughout the world, there is still disagreement as to whether this is a subject that can be taught." Nonetheless, such training or books give general guidance on commercializing an invention. You do not become an instant millionaire!

4.2 Mentors

"I was simmering, just simmering till Emerson brought me to a boil: Walt Whitman." (Walt Whitman was a great American poet and Ralph Waldo Emerson was a great American philosopher). This statement sums up the value of a ***mentor*** in starting and running a business. However, in the modern age of wireless world, it is not possible to have a mentor who can afford the time to help you (unless you have the money to pay for

his/her service). This does not mean that you cannot have a mentor. There are and, there were many business leaders, spiritual leaders and heroes in the world who can be your inspiring virtual mentors. Take for example, Abraham Lincoln (**9**):

Lincoln's Road to the White House

Failed in business in 1831.
Defeated for Legislature in 1832.
Second failure in business in 1833.
Suffered nervous breakdown in 1836.
Defeated for Speaker in 1838.
Defeated for Elector in 1840.
Defeated for Congress in 1843.
Defeated for Congress in 1848.
Defeated for Senate in 1855.
Defeated for Vice President in 1856.
Defeated for Senate in 1858.
Elected President in 1860.

So, what does this great hero teach us? He teaches that if you wish to succeed you must have: confidence and belief in yourself, the belief in your invention, your vision (dream), stamina, perseverance, integrity, patience, and so on.

Other exemplary individuals, just to quote a few examples, are:

Mohandas Gandhi (10): One learns, among other things, the art of conciliation vis-à-vis confrontation (however, in some cases, only confrontation seems to be the choice).
Conrad Hilton (11): Whenever he had issues with the business, he went to his mother for advice; all she did was to ask him to go the church down the road to pray for an answer, which he did. Does prayer contribute to success or, should we discourse with God, just as ***Job*** (**12**) did?).
Soichiro Honda (13): You will learn how to tolerate ***humiliation*** and to deal with many obstacles, which invariably occur to almost everyone who starts a new business. Briefly, here is his story: He was a poor student (often pawned his wife's jewelry) and, after years of effort, designed a piston ring he was sure Toyota would buy. When he took it to them, they rejected it. He went back to school to suffer humiliation of his teacher's and friends' telling him what an idiot he was for designing such a ridiculous gadget. Did he give up? No, he continued to refine the design till finally Toyota bought it! He suffered many more hardships, but today makes unbelievable number of products sold all over the world.
Nelson Mandela (14): He freed South Africa after years of struggle, which included spending most of his life in the dark dungeons infected with mice, cockroaches, centipedes, blood-stained blankets, bare floors with disgusting stench. He is a true symbol of courage, patience, perseverance, stamina and strength, all of which are essential ingredients to achieve success in any endeavor.
John Marriott (15): Teaches you the importance of rendering impeccable service to the clients. His tradition is still alive in all the Marriott hotels around the world. Since the very beginning VLN has followed his example.
Mother Teresa (16): The most illustrious person in the modern world. Born in Albania, left her parents at the age of nine and never saw them again. Made her home among the poorest of the poor in India, giving hope to those who had no hope. She is a true symbol of ***humbleness***, among other great qualities, which is necessary in running a business.
Sam Walton (17): Everyone knows Mr. Walton, the father of Wal-Mart.

In summary, at moments of uncertainty, despair and anxiety attacks (there will be many) these virtual mentors will empower you to move on.

4.3 Ego (*E*dging *G*od *O*ut)

Before granting me seed funding, NRC asked me to submit a business plan. It was turned down because on each page I had bragged about myself, that is, about my publications, reports, my reputation from Australia to California! I wrote, "Since I am so well-known in the world, I can sell hundreds of FPWJ machines!" The net result was NRC hired a business consultant to write my business plan and my "***ego***" was simply tossed out from it. Yes, your engineering and scientific achievements have some bearing on commercialization, but they do not make you sell your machines.

4.4 Incubation Period

The popular notion is that a new company needs about five years before it can start to sell its products. Not according to Skoczkowski (used his money like myself) who, like many other innovators, has been trying to commercialize his invention (**18**). According to his statement, it takes about 10-years before you and your products become known to the end-users, which is quite true.

4.5 Whom You Know Matters More Than What You Know

Yes, your invention is brilliant (or, you think it is so), but in the real world, unless you know someone influential (a politician, a CEO of a large corporation, etc), you might as well let it rest it under your pillows. I have taken this bitter pill from the very beginning (12-years) and it is only now that we are getting noticed. Yes, if you have all the money in the world, you can hire highly influential individuals (for example, lobbyists for winning government contracts), to manufacture and sell your products. Since you do not have that "money," the only recourse is patience and hope!

4.6 Human Resources

In order to commercialize any invention, one needs highly committed, dedicated, well-qualified individuals with unquestionable integrity and sincerity and, who share your ***dream*** with equal passion. Sometimes, the company is in desperate need for an employee, and you hire someone simply because the person's professor/supervisor happens to be once your ***friend***. This practice is not in the best interest of the company (although you are doing a favor to your friend), unless you do a thorough search on the individual, have in place a legally enforceable and iron-clad "confidentiality and, nondisclosure" agreements (especially if the person is from another country). This does not, however, guarantee that the individual will honor his/her commitment (see below about "***paradox of patents***") to the company. With the exception of one such individual, I am extremely fortunate to have exceptional individuals working with me (they are as committed as I am to my ***MISSION***). It has been possible to put together this dedicated team through my understanding of their needs, compassion when warranted, teaching (sometimes with frustration), that is, keeping their well-being and interest ahead of my own.

4.7 Finance

There is nothing new about this. We all know, nothing moves in life without money! When I revived VLN in 1998, as a spin-off company from NRC, there was a big hope

that BDC (Business Development Bank of Canada, a Crown Corporation of Canada supposedly established to help start-up companies) will ride along with VLN. I have yet to see an investment (loan) of one dollar from BDC to VLN. Simply put, getting money to finance the development and marketing of your product is a nightmare, which is echoed by the recent report from CFIB {Canadian Federation of Independent Business, (**19**)}, which pin pointed that the banks are the worst institutions to go for loans. So, where are the other financial resources?

- **Personal:** This is investing your own money into the company. In my case, I sold five condominiums which I and my wife owned (two in Florida purchased for retirement), my retirement savings, taking line of credit on our home, cashing all the bonds, my wife's salary and continuing to borrow heavily from credit cards. Here the banks are quite crafty. They will not give you lines or credits or, other forms of low interest bearing loans, but depending upon your track record, they will increase the credit limit on your credit cards because the interest rate is in the neighborhood of 21% (some charge up to 29%). If you are smart, there is a good chance to get around this as some banks, quite often, send you the so-called convenience cheques that can be used to pay off the high-interest balance owed to other banks. The interest rate offered (by the convenience cheques) varies from 1.0 to 3% for a fixed period of time (6 to 9-months). If you can use this ploy, the overall (average) interest you will be paying will be of the order of 6 to 10%, which is quite reasonable.
- **Loan from Associates (Employees):** This depends on the extent of confidence they have in the product, the owner (that is, me) and their own financial resources. At times, I was fortunate to borrow from my associates.
- **Venture Capital (VC):** After trying a few times, we gave up. In one case, the broker told us that our application was refused because I did not wear proper dress with a tie (it was humiliating, but I just ignored it as I had no interest in the VC!).
- **Angels:** They are called angels because they are willing to finance you. However, they are not inexpensive. The interest rate ranges from 15 to 20%. But when you need it, you have no choice.
- **Loan Sharks:** There are some individuals (or, financial companies) who will lend you the money based on your receivables {purchase orders (PO)}. They will retain up to 10% of the PO for the first 30-days. If the loan is not paid within the due date, then you will lose another 10% (amounts to more than 200% annual interest rate). When you have exhausted all other avenues, this is the only recourse you have.
- **Reverse Takeover:** Details on "reverse takeover" can be found on the internet. This is another way of seeking finance for the company. However, if you are not careful, you may not get the benefit you are looking for (you may be gobbled up). This is where one of my friends became a stranger because I did not go for it (see below).
- **Funds from the government:** There are several programs under which governments fund the research and development projects that lead to commercialization of inventions (probably are available in all countries). However, for some of these programs there is a competition between the small private companies (like VLN), large corporations (often multi-nationals), government research departments and the universities. Often, the latter three get most of the funding with very little or nothing for small private companies (unless you have connections). Fortunately, in Canada, there are two excellent programs: (1) Industrial Research Assistance Program (IRAP) administered by NRC and (2) SR&ED (Scientific Research & Engineering Development) program earmarked by the CRA (Canada Revenue Agency). The latter is the most attractive program under which private sectors are recognized for their R&D efforts and are rewarded by cash

or, tax credit depending on the annual review of the projects by a scientific advisor of CRA. If this funding were not available, I would not be writing this paper today.

- **Piggyback:** This term simply means associating your company with large corporations with substantial financial resources. This situation arises when you realize that you cannot make it on your own, but still strongly believe in your invention. In 2002-2003, it became quite clear that VLN needs this piggyback. I contacted several companies around the world seeking some type of partnership. Except one company, the responses were negative. This company asked me, however, to take the entire machine to their location at my own expense so that it could be tested for several applications to make a decision. Obviously this was not possible. Somehow VLN managed to survive for the next three years and the situation became desperate again in 2006. This time one company showed serious interest as FPWJ was capable of stripping hard coatings without damage to the parts. Here was the condition: "VLN must let us keep the 138-MPa RFM at our facility for 90-days for thorough testing and evaluation. If at the end of this period, if the performance is acceptable, we will purchase it and negotiate future possibilities. If not, we will return it." You guessed it right. This humiliating offer was tossed right through the window. To summarize, it was not possible to find an honest company for piggyback.

In conclusion, financing the development of a commercial product from the invention is a formidable task. As stated above, with loans from angels, our personal investment (≈ $1.5-million), small funding from IRAP and SR&ED credits, I have managed to develop the FPWJ machines to the present stage (at a cost of ≈ $5-million over the 12-year period).

4.8 Governments

As is obvious from the statements made above, there are some government departments which are quite compassionate and understanding when it comes to small private enterprises. However, there are a number of other government departments which are quite intimidating and almost hostile. If you do not pay whatever is due to be paid in time, even as little as $1.00, you will receive continuing barrage of intimidating letters to pay up. If not, you are subject to heavy penalties or, deal with collection agencies and eventually your bank account will be frozen, which has devastating consequences on the credit rating of yourself and the company, employees, suppliers, etc (so-called ripple effect). The lesson learnt from this experience: "Do not upset these departments."

4.9 Friends (Including Relatives) Become Strangers and Strangers Become Friends

Perhaps most of the entrepreneurs face this unfortunate circumstance. Just as an example, about 4-years ago, I visited (at my own expense) the president of a large company whom I have known for more than 25-years. Since his company is well-known and has been in business for more than 50-years, I offered him one of my inventions for commercialization (gave him all the technical drawings, including the nozzle for testing). The condition for this transaction was very simple: "the company must pay a minimum of 25% of the profit made from the sale of this product to UNICEF (United Nations Children Fund)." A few months later, I received his letter which stated, "Your invention is ***not as good as ours*** and therefore, we are not interested in its commercialization." Learning from Honda, it was easy to accept this humiliating response. While I have lost many of my friends (including professors) of years ago, new friends, who firmly believe in the FPWJ technology (and perhaps, my sincerity), have sprung up in the past seven years.

4.10 Nondisclosure and Confidentiality Agreements

It is a common practice to endorse confidentiality and nondisclosure agreements between collaborating parties, visiting clients (including students and trainees) and employees. The validity of these agreements, however, depends on the sincerity and integrity of the individuals who endorse the agreements. This is often a major concern for small companies, especially when the visitors are from foreign countries whose language is not English and therefore, do not understand the implications of violating the agreements (often leads to pirating the technology when the person returns to his/her country). In one case, a large multi-national corporation attempted to force me to sign an agreement, in which ***surface prepping*** with the FPWJ was stated as their idea and not mine. This was totally unacceptable as VLN had already demonstrated its potential for prepping surfaces for other end users (**3**). Therefore, often it is good to seek legal advice before endorsing any of these documents. Nonetheless, unless the violation of these agreements could be legally enforced (which is virtually impossible in foreign countries), significance of these agreements remains questionable.

4.11 Paradox of Patents

Patent! The word sounds so great. Is it really, when one considers the dedication, efforts, money, personal sacrifice and time it takes to get one, especially if one goes after international patents? Okay, you get one and then suddenly you discover that someone or, some corporation in your own country or, elsewhere in the world, has stolen your invention, using it for their own financial gain. Infringement of patent rights is universal (**20** to **26**). In other words, in the real-business world, unless you take proper measures (at considerable legal expense), having a patent is no guarantee that your ***genuine*** invention will be protected. Possible factors that contribute to this widespread violation of patents are briefly listed below:

- Publication of the patent application by patent offices while there is no certainty that you will eventually get one (I have been told that in the USA you can request the patent office not to publish the application). With respect to our application (**2**), it was submitted to the international patent office {PCT (Patent Cooperation Treaty)} in November 2003 and it was published as WO 2005/042177 A1 in May 2005, following which applications were submitted to several countries. While we have the patent in Europe and USA, and still pending in Canada, China and Japan, someone or, some corporation has access to the WO2005/042177. This document is actually a blueprint for manufacturing the FPWJ machine. Therefore, it is easy for the person or the corporation to manufacture it or, making a few changes (re-engineer) could file for a patent, to start with, in their own country. So, what can you do about it when you find out that it has indeed happened? When you do discover, is it easy to stop infringement except recourse to expensive and time consuming lawsuits (see references **27** to **32**)?
- Here is another scenario. Consider, for instance, the patent in Europe. One would have thought that it is automatically valid in all the countries that are members of the European Community. Unfortunately it is not the case. One has to submit the patent to each country in Europe for validation at considerable expense (some of the countries require the entire document to be translated into their national language). If you do not validate the patent in a country that is part of European Community, then any one in that country can exploit the benefits of the technology, for use in that country. Yet another paradox is, some countries, for example, Norway and Poland, do not validate the European patent (need to submit another application!).

Therefore, anyone in these countries can use the patent and there is nothing you can do about it!

- Sometimes the patent office issues patents that should not have been issued (**29**) in the first place. This happens because the examiner has limited resources and has no access to relevant published or unpublished data, which forces him to rely heavily on information submitted by the applicants (**29**). Therefore, if the patent is issued to someone who should not have been granted, then the recourse is impeachment of the patent (**30**, **31** & **32**). How about the fraud? This can also happen (**29**).
- It is a known fact that the commercial value of a patent depends on the duration of its validity, normally 17-years. The paradox here is that the duration is not from the date of issue of the patent. It is from the date of original submission of application. Thus, in our case, the European patent is only valid for about 10-years. The only solution to this paradox is to continue to improve the product and apply for new patents (if you have the financial resources).

To summarize, in the face of all these threats, how do you succeed in commercializing your invention? Yes, you can do it by: (1) retaining your own integrity and reputation, (2) continuing to improve your invention so that you are light years ahead of those who steal your invention and (3) if at all possible, discredit the persons or corporations who pirate your invention.

4.12 Other Factors

Your innovative product is ready for marketing but you have stiff competition. You must be ready to face the challenge by financing (one bank told me bluntly, "If you wish to be big, you must act big (even if you do not have the money!"):

- Promotion by printing brochures, displaying your products at expositions, writing technical articles, etc. Over the past 12-years, VLN has spent about $0.4-million to promote FPWJ machines (unfortunately, displaying and demonstrating the products at expositions have not been successful).
- Marketing, which also involves preparing business plans, market research along with promotion.
- Visits to potential clients' sites.
- Hospitality (drinks, lunches and dinners, the cost of which adds up).

The most important requirement is gaining clients' confidence by being humble and ready to serve.

4.13 Nightmares and Anxiety Attacks

It is quite clear from the description given above that it is almost impossible not to have nightmares and anxiety attacks. The factors that contribute to these debilitating feelings are: 'no money', 'fear of failure', 'premature termination of contracts and purchase orders (without any explanation)', 'fake purchase orders (my anxiety attack was at its peak when one client, a friend of over 30-years, did place a fake order), 'debt payments', and others. Unless, you learn how to deal with these feelings, you will most likely fall sick or, even end your life. I have managed to overcome these debilitating feelings by regular MEDITATION and PRAYER. Needless to say, unless you have the compassionate support of your family members, meditation or, any other technique will be futile.

5 CONCLUSIONS

In the face of all these daunting facts, did I make the right decision to commercialize the FPWJ technology? Yes, I did. When I decided to launch VLN, the vision was not just to make money to lead luxurious lives. It was to make the world a better place for children to live by establishing a benevolent foundation. VLN is on the verge of accomplishing that vision or, in the words of Conrad Hilton, "ACHIEVING THAT DREAM." It is fitting to quote the words of Lightman (**33**), "*For those who have had their vision, this is a world of guaranteed success. For those who have not had their vision, this is a world of inactive suspense. Such people sleep most of the day and wait for their vision to come.*" The vision can only be achieved by the confidence in yourself, belief in your genuine invention, hard work, commitment, dedication, patience, perseverance and by making every effort to turn stumbling blocks into stepping stones.

6 ACKNOWLEDGMENTS

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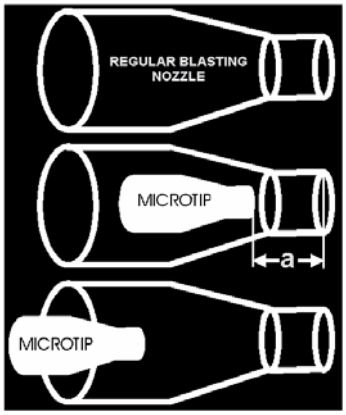

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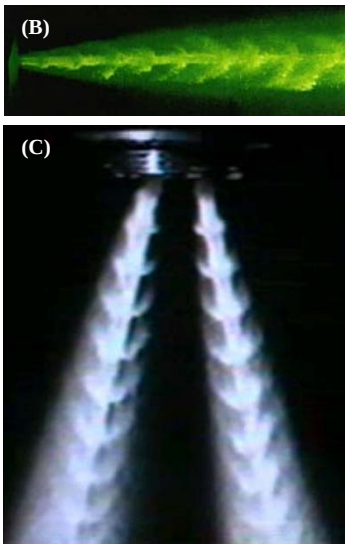

Fig. 1. (A) Method of generating FPWJ by placing a microtip (probe) inside a regular nozzle (**1**).
(B) Structure of FPWJ emerging from a single-orifice nozzle assembly and (C) Structure of FPWJ emerging from a dual-orifice rotating or non-rotating nozzle assembly.

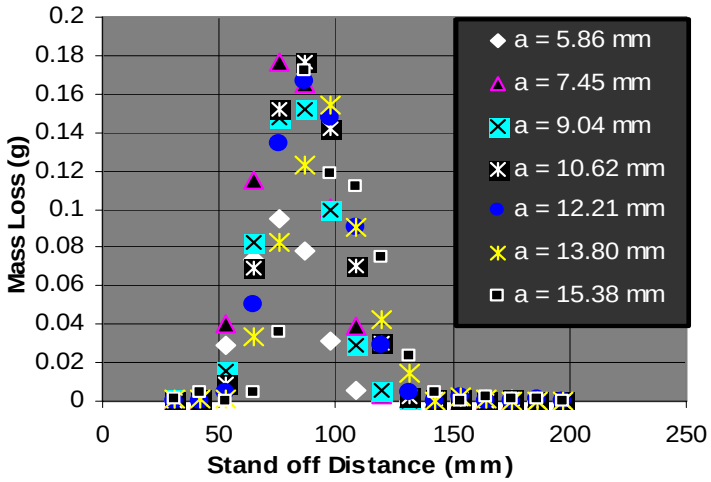

Fig. 2. Plot of mass loss of aluminum samples as a function of standoff distance at various values of 'a' as indicated. Orifice diameter = 1.625-mm, Pressure = 69-MPa and A_m = 50% (**2**).

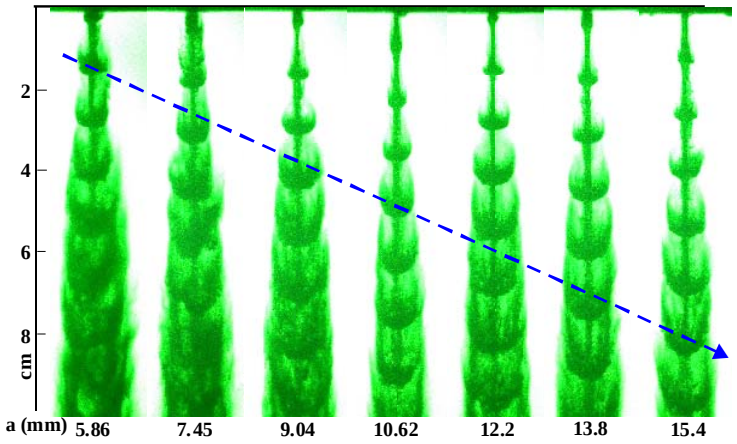

Fig. 3. The effect of the position of microtip on the structure of FPWJ: d = 1.37-mm, P = 34.5-MPa & A_m = 50% (**5**).

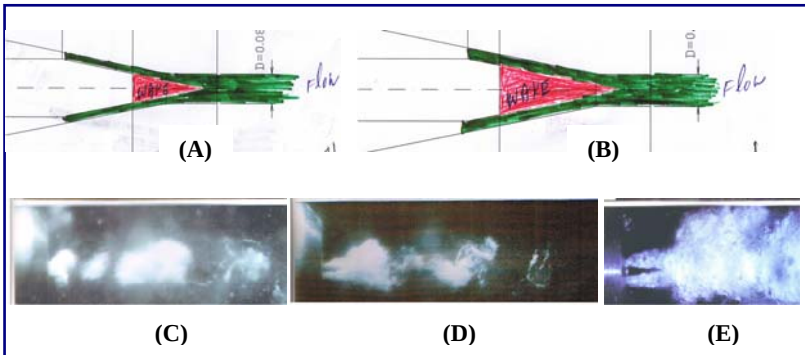

Fig. 4. Formation of wake downstream of the microtip.
(A) & (B): Hand-drawn streamlines showing the extent of the wake which depends on the position of the microtip upstream of the nozzle exit, orifice diameter, geometry of the nozzle, pressure and A_m (amplitude setting on the ultrasonic generator.
(C), (D) & (E): Photographs showing the existence of the wake (taken from Ref. **6**: submerged cavitating waterjet emerging from a nozzle with the pin, similar to the microtip).

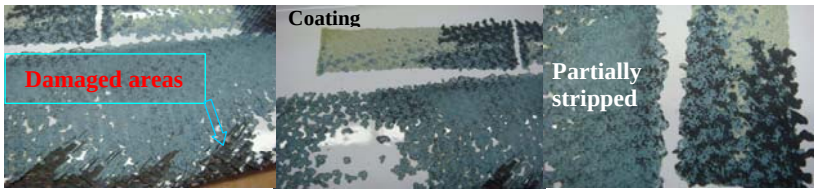

Fig. 5. Highly challenging task of stripping epoxy coatings from substrates consisting of several types of composite materials.

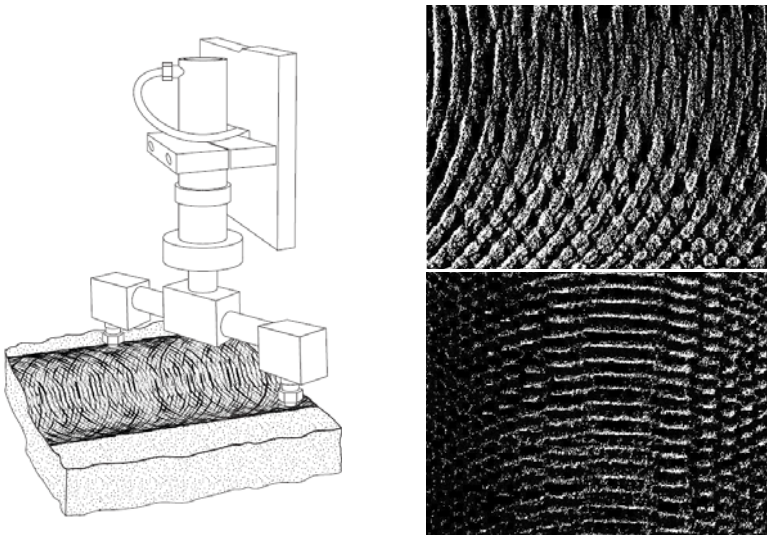

Fig. 6. Prepping surfaces of building stones (granite, marble, etc) with the rotating FPWJ nozzles (2). Note: the author had conducted prepping investigation with continuous waterjet in the 1980s – presented the paper at the International Waterjet Symposium at Beijing, China in 1987.

Fig. 7. Prepping the wooden floor panels for injecting resins. Penetration of the red dye indicates that FPWJ with the appropriate operating parameters has the potential to treat wood surfaces (2).

Fig. 8. The first FPWJ machine manufactured in 1996-97, using magnetostrictive transducer located inside the nozzle assembly (single-orifice.

Fig. 9. The second FPWJ machine manufactured in 1998 under contract from the Department of National Defence, Canada.

Fig. 10. The current FPWJ machine designed and manufactured for use with multiple-orifice nozzle assemblies.

Fig. 11. Model 69-MPa RFM (retrofit module) 20-kHz pulsed waterjet generator.

Fig. 12. Model 138-MPa RFM.

Fig. 13. A general view of the TURN (device consisting of ***T***win ***u***ltrasonic ***r***otating ***n***ozzles.

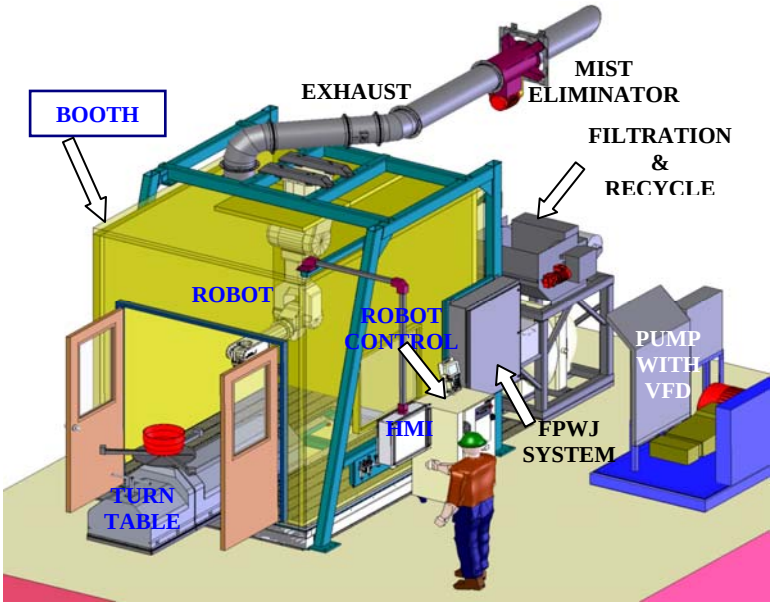

Fig. 14. Conceptual design and layout of the APWSS based on extensive computer simulations.

Fig. 15. A general view of the new booth with well insulated walls.