# DYMET Technology Evolution and Application

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**Abstract**

High requirements of Cold Gas Dynamic Spray (GDS) process caused the development of low pressure DYMET technology. The technology and equipment evolution is presented and discussed. Modern portable low pressure DYMET equipment may be easily applied for various technical problem solutions. Multiple applications are briefly described.

**Introduction**

Originated in 1992, DYMET technology [1, 2] is based on the solid particles acceleration in the supersonic nozzle by compressed air. In contrast to the usual Cold Spray [3] approach, this process employs the powder injection to the air jet downstream the nozzle throat. Because of low stagnation pressure and downstream injection accelerated particles can not approach the velocity necessary for Cold Spray process [4]. But the special use of metal and ceramic powders mixtures allows the creation of thick coatings [1, 5].

The typical DYMET equipment includes compressed air heater, supersonic nozzle with radial powder injection downstream the throat and powder feeder. Use of ceramic particles in the jet requires special nozzle design. The same time downstream the throat powder injection allows the use of open powder feeder.

The technology and equipment development were aimed at the reduction of compressed air and power consumption and to the equipment weight and dimensions decrease. The purpose of this development was directed to the possibility of GDS technology use at small plants and shops.

The same time optimal powder mixtures were investigated for different applications. The main purpose of powder mixtures development was to solve various practical tasks on the basis of minimum mixtures variety.

**Equipment and Technology Evolution**

First practical application of DYMET technology in 1996 was concerned to the space industry. Thick aluminum coatings were developed and approved for special tasks [6, 7]. "DYMET-200" equipment (Fig.1) of 10 kW power used compressed air at 0.8 MPa and air flow rate 2 $m^3$/min.

Some changes of equipment this period concerned various nozzles modifications like external cooling (Fig.1 right) and direct nozzle multiplication (Fig.2) for different industrial applications.

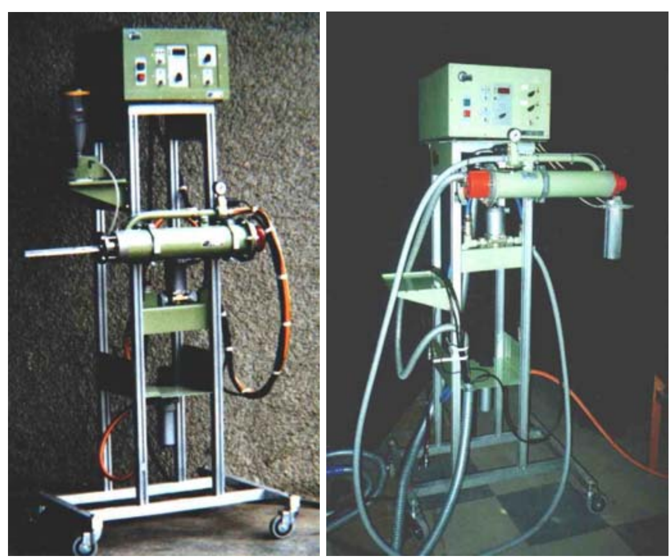

*Figure 1: Equipment DYMET-200 in 1996 (left) and DYMET-204 in 1998 (right).*

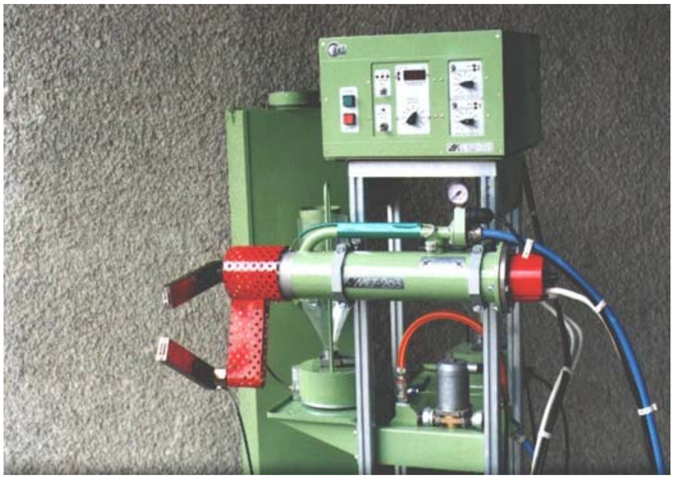

*Figure 2: Equipment DYMET-203 in 1997.*

Further development was aimed to the total air feed rate reduction. New types nozzles were designed. A deliberate powder deposition efficiency decrease was chosen as the compromise for the sake of process requirements reducing. Diminished air feed rate and nozzle size result in the possibility of portable equipment design. The simplest version DYMET-400 could be placed in two brief cases (Fig.3). Portable design allows the use of hand GDS gun (Fig.4) and was realized in compact equipment models (Fig.5).

The main process requirements achieved in modern state of DYMET technology are as follows

- compressed air pressure of 0.5 MPa,
- compressed air feed rate of 0.4 $m^3$/min,
- electric power supply 3.5 kW.

Early in the development of DYMET nozzles special changeable plates were used as internal nozzle surfaces downstream the point of powder injection for the quick

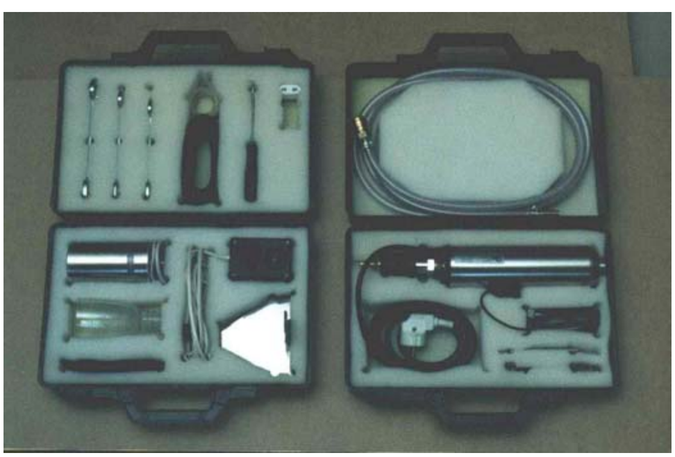

*Figure 3: Equipment DYMET-400 in 1998.*

*Figure 4: Hand GDS gun of DYMET-402DC in 2001.*

warned nozzle profile restoration. The new types of nozzles consist of main part, including the nozzle throat and injection unit, and replaceable insert as the diverging nozzle part. The nozzle design continues to be in development to improve powder distribution in the jet and minimize nozzle changeable part wearing process.

Being the subject of technological process, special powder mixtures have to be designed for various applications. Two and three component optimal mixtures are mostly used now to spray coatings. Some copper based and nickel based multi-component mixtures are developed for combined spraying-annealing processes.

Powder recuperation is hardly possible for multi-component powder mixtures because of components proportion changes but dust collection is necessary for the process safety. The spraying system of the portable DYMET equipment may be combined with the dust collecting system like cyclones (Fig.5 left) or filters for safe and convenient operation process. This approach to equipment design is realized now by Centerline Supersonic Technology Division [8].

*Figure 5: DYMET-401 in 1999 (left) and DYMET-402DC in 2001 (right).*

## Modern Portable Equipment and Powders

Modern DYMET equipment is compact light weighted gas dynamic spray machine with GDS spray gun, two powder feeders and control unit (Fig.6). Control unit includes air pressure and air temperature control and powder feeders switch with powder feed rate regulators. Compressed air line has to be connected to the air inlet and operating air pressure may be adjusted to the required value by pressure regulator. Several discrete temperature settings are intended for the quick easy choice of the optimal spraying parameters. Powder feeder switch allows quick change between two powders.

GDS spray gun includes light weight air heater and supersonic nozzle [9, 10]. Both round and flat nozzles may be attached to the gun (Fig.7). The specific modern DYMET nozzle includes replaceable nozzle insert as a changeable element eroded by powder mixture. The powder injection unit in the nozzle is designed for optimal powder distribution inside the nozzle and minimization of nozzle insert wear. The radial powder injection downstream of the nozzle throat maintained in all DYMET nozzles allows the use of open powder feeders.

The GDS gun is optionally equipped by single powder button switch or by handle with the trigger for air and powder switching on. Both may be easily disjoined for the use of the gun in robotic operation.

Two open powder feeders keep uniform powder supply for 15 minutes each and may be uploaded during the operation. Regulated powder feed rate may be maintained up to 3.5 kg/hour.

The modern DYMET powder mixtures are based on alumina and silicon carbide ceramics and aluminum, copper, zinc, nickel, lead and tin. The optimal powder mixtures are

*Figure 6: Portable equipment DYMET-413 in 2006.*

*Figure 7: Former and modern DYMET nozzles.*

developed for different practical applications. In practice two or three component mixtures are mostly used. Optimization process includes adhesion and cohesion measurements, porosity investigation and deposition efficiency evaluation.
The proper choice of mixture composition allows obtaining coating properties for specific task solution.

Because of the possibility to produce coatings on different metal surfaces the same problem can be solved by the same powder material at different objects. For instance the same powder mixture can be used for sealing off the leakages in various metal pipes. Based on this approach several unified powder mixtures are developed for the most typical problems. These mixtures are supplied to DYMET users packed and ready to use.

## Application

Several typical problems often encountered in industrial and restoration processes may be solved by gas dynamic spraying. Most of them are connected with the needs to build up material to the metal part without part overheating inherent to welding process.

The aluminium moulds repair and shape modification are the typical problems in the plastics industry. The use of portable DYMET equipment with proper powder material allows mould modification without undesired thermal strain (Fig.8). In most cases gas dynamic spraying and following machining are much less expensive then new mould fabrication.

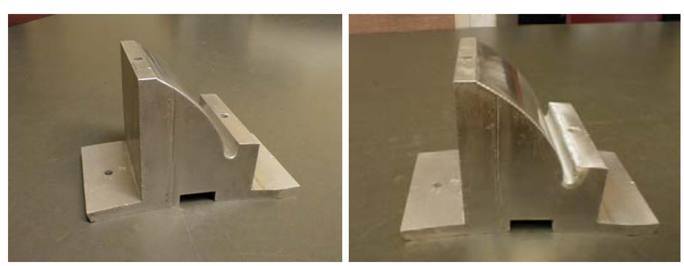

*Figure 8: The modification of aluminum mould profile by DYMET spraying to the local mould section.*

*Figure 9: Restoration of corrosion defect on car engine by spraying aluminum based powder mixture.*

Many repair processes encounter lack of metal on the parts. These lacks may be caused by corrosion or wearing processes or by other means. In some cases welding requires high personnel qualification and may be undesirable because of possible part thermal strain. The use of DYMET technology makes the solution quite simple and built up material may be machined in usual way. Both aluminum and cast iron engines are often repaired by the same aluminum based powder mixture in the small car repair services (Fig.9). Eight years practice has confirmed the reliability of car engine restoration by this way. Many car repair services and motor depots in Russia use portable DYMET equipment for car parts restoration. The restoration of worn bearing beds, copper casting funnels and other large machine parts just at the part location also have been executed by the use of portable equipment.

The casting defects are the typical industrial problem. Encountered after complex machining in the short-run production, those defects are the subject of material and profit losses. Just as in the case of parts restoration the casting defects can be removed by local gas dynamic spraying (Fig.10). Depending on the requirements to the part necessary powder mixture may be chosen to restore the lack of metal. In many cases it is not necessary to spray the same metal as part is produced of to solve the problem. Nickel or copper or aluminum based coatings at steel and cast iron parts often satisfy the customers. Aluminum based powder mixtures are successfully applied to restoration of casting defects for various aluminum alloys.

*Figure 10: Filling the casting defect on the steel part by aluminum based coating.*

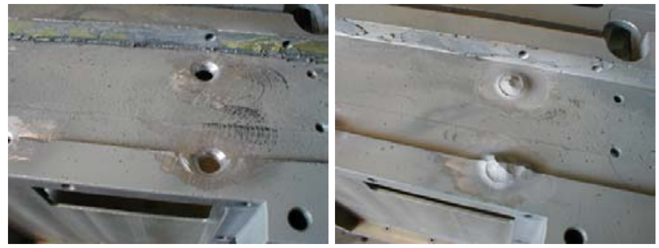

*Figure 11: The sealing of the holes in the aluminum case.*

The problem of sealing up the holes is encountered in various technical services. Polymer glues are not applicable in many cases. The correct choice of powder mixture and DYMET equipment settings allow the sealing up leakages in metal parts by gas and water impermeable metal coatings. In the case of large holes any metal plugs may be used to diminish the entire holes dimension (Fig.11). Because of low heating of the substrate the sealing up process is applicable even to thin-walled aluminum tubes. Due to the possibility to spray thick metal coatings to any metal the joint impermeability can be achieved for the mechanically joined parts of different metals like aluminum and steel or aluminum and copper.

Along with the thick coatings for building up material the thin corrosion protection coatings are often sprayed to local sections of the parts. Local zinc coatings are mostly applied to the welding lines of preliminary galvanized and welded afterward large metal constructions. Local zinc or aluminum coatings are also used at the small car services for local car body and other parts corrosion protection (Fig.12). Required corrosion protection of the points of ground connection by local zinc coatings spraying is applied in industry to avoid galvanisation of the large electric equipment cabinets. The portability of equipment is the necessary condition in most cases of local coatings spraying.

The possibility of local coating spraying is applied not only for technical tasks solution but also for art design and antique art objects restoration. In some cases the use of gas dynamic spray process is the only applicable method of restoration. Portable DYMET equipment was used to restore lost zinc coatings at the antique rotary elements of Angel at the Cross rotating sculpture at the broach of Saint Peter & Saint Paul

*Figure 12: Corrosion protection coating at welding lines.*

*Figure 13: Restoration of the lost copper coating at the antique sculptures of Isaac Cathedral in Saint-Petersburg.*

Cathedral in Saint Peter & Saint Paul Fortress and to restore lost copper galvanic coating at the antique sculptures of Isaac Cathedral in Saint-Petersburg (Fig.13). Because of equipment portability the restoration process in both cases was fulfilled without antique elements and sculptures dismantling.

In spite of the limited deposition efficiency DYMET gas dynamic spraying process is attractive for short-run production by its low requirements and high adhesion of the coatings. Because of light weight of spray gun it may be inserted into any robotic system to produce coatings of desired shape at desired location. This process is mostly used in electrical industry to create or modify electric contacts. The simple X-Y manipulators are used to spray flat coatings of the desired thickness. Typical applications are local metallization of ceramics (Fig.14) and electric contacts corrosion protection by tin or aluminum or copper.

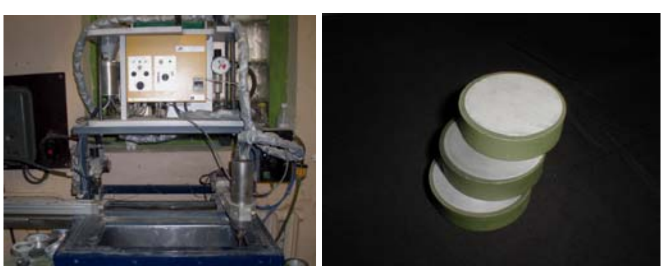

*Figure 14: Simple automatic system for ceramic surface metallization and ready to use varistors.*

## Conclusion

DYMET technology evolution was directed towards the reduction of compressed air and power consumption and the decrease of the equipment weight and dimensions. The reasonable powder deposition efficiency decrease was accepted to achieve the compromise between the customer's needs and possibilities.

Because of low process requirements portable DYMET equipment now may be used both in small repair shops and manufacturing plants. Ready to use optimized powder mixtures are designed for various applications. In spite of the reduced powder deposition efficiency DYMET technology offers possible solutions to wide variety of technical tasks.

Modern technology is used for renewal and restoration of machine parts, local corrosion protection, moldings modification and other purposes. Up to date portable DYMET equipment is employed by several hundreds of repair shops and manufacturing plants in Russia.

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