

## DORST Netshape® 4.0 – The Next Step Towards Autonomous Manufacturing

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### Abstract:

In the production of green parts from powder, there is unavoidable slight deviation in the die filling, even when high-quality powders are used. The quantity of powder in the die varies and thus affects the weight of the compact. This filling variation results in variation of the pressing force, and thus influences the part geometry.

The development of the DORST Netshape® System was conceived as an autonomous manufacturing system in order to compensate for these effects. Based on the Dorst Industry 4.0 innovations for part weight measuring immediately after pressing in combination with a laser dimension measuring system, this technology package attempts to reach enhanced precision and consistency in production.

The paper presents results from various trials that show the capability of this new system, designed to improve the quality of pressed parts.

### **Keywords**

Additive Manufacturing, 3D printing

## **1. Introduction**

Despite the fact that tolerances become tighter with every new generation of parts and the designers succeed to create even more complex geometry, the optimum quality of compacts is – more than ever – a mandatory requirement of the end users of parts pressed from powder. The complex geometry is taken care of by sophisticated machines, densifying the powder with up to 11 closed loop controlled individual punches. Often, the high demand for tight tolerances is solved by additional machining, which is a costly solution and should be avoided.

However, the optimum quality is not only a task of the compaction stroke of the powder press, but also a function of the powder. Its characteristics such as filling behaviour, flow rate etc. severely influence the result of the press procedure. What to do to control this bouquet of parameters?

Thanks to today's available possibilities of electronic control and highly developed software, there is the chance to fulfil end users demand and avoid subsequent machining.

Today the software Intelligent Program Generator IPG® calculates the optimum pressing cycle, which is unique for every individual compact. Unfortunately, the actual conditions during the compaction of the powder are never identical to the theoretical ones and the influence of the powder parameters and the mechanical constraints of the machine have to be part of the algorithm. This only can be realized by measuring the actual data of the current press cycle and apply them immediately to the densification process, in order to adjust the next following press cycle accordingly. To integrate these influences into the calculation DORST Technologies developed the software Netshape® and now combines it with the potential of Industry 4.0 – measurement of compact quality.

The refined approach to improve the results of the compaction cycle by Netshape® 4.0 – are the objective of this paper.

## **2. The pressing process**

### 2.1 The press cycle

For every compact, there is only one optimum cycle of densification. This has to consider the following items:

- Press force in total
- Press force separated to the individual levels
- Movements of every punch for powder transfer and powder compaction
- Filling height and compressibility of the selected powder mix

Based on these data the cycle of all required movements is calculated, which can be easily done by everyone, familiar with powder pressing technology. This entire cycle is a pure theoretical one and fully independent from the kind of powder press applied and its individual capabilities.

## 2.2 The powder press and the tool

For the production of the compact, there is always a particular machine with its individual capabilities and physical (re)actions on the pressing cycle, which basically are:

- Elongation of the press
- Deflection of the punches

These need to be considered, to assure proper movements and to produce a correct pressed part. Therefore, the press' and die set's mechanical properties, such as rigidity and stiffness have to be taken into account, when the movements of the press cycle are calculated.

As you see, also the tool design has influence, because the punch length and punch support mainly determine the deflection under maximum load.

Due to these facts, the theoretical cycle will not work in practice for the production run. Thus, after the software tool Intelligent Program Generator IPG® calculated the theoretical cycle and before starting the production run, the setter has to measure the actual dimensions of the pressed part. Then he feeds these figures into the control system DVS/DCS®, to enable the IPG® to re-calculate and optimize the cycle with reference to the actual elongation of the press and deflection of the tool, thus the deviations of the entire system. This procedure balances the pressing cycle in accordance to the individual physical condition of the press system.

## 2.3 The powder mix

As a matter of course, the powder and its characteristics have remarkable influence. Depending on the individual parameters of every powder mix, such as:

- Apparent density
- Compressibility
- Flowrate
- and some more

the press cycle needs adjustments in accordance to these data, too. This is automatically concluded, when using the software IPG® as described above. The optimisation function integrates the powder characteristics into the calculation, by the actual measured data, although the system does not know the real figures.

## 2.4 Influence on the compact

As long as the powder quality is stable within tight tolerances, the system comprising press, tool and powder will produce high quality compacts.

In daily production, i.e. on the long run, part makers face challenges to maintain constant quality and to keep the tight tolerances of the green parts. Due to any production break and re-start or change of powder bags, it comes to unavoidably deviations of the compact quality.

Upon each of these events, the system leaves the stable production state and the optimum press cycle. As on a new production start, it will produce for a short period some scrap parts, before it returns to the stable state.

The setters counteract to this well-known effects, by correcting the cycle, adjusting it to altered conditions. They do this by a new optimisation via IPG® or by manual interference. Nevertheless, in both cases, the machine is taken care individually and not kept autonomously in proper production.

In addition, also the change of other parameters, like temperature and humidity, influence the powder behaviour and consequently ask for re-adjustment of the press cycle to keep the high quality level.

## 2.5 Possible correction of unwanted changes

To achieve constant results in part density and dimensions, while keeping tight tolerances, it is mandatory to adjust the pressing cycle in accordance with the actual powder fill in the die.

The CNC powder press provides at every stroke the identical shape and volume with very high accuracy. In addition, it keeps the pressing position, thus the final dimension of the compact, exactly during every stroke.

The variation of the powder, due to modification in its parameters, change of the powder-lot or a production stop have an effect on the weight and thereby on the density of the green part. On multilevel parts, this has an important influence on the grading of the height steps. The precisely calculated and executed movements of powder-transfer and densification for each individual punch do no longer fit to the modified properties of the fill, thus leading to the effect of undesired horizontal powder transfer, causing cracks. Consequently, also the machine-movements and -speed, thus the entire compaction cycle, has to be adapted to the altered conditions.

### 3. Press Trials to verify the DORST Netshape® 4.0 – system

To evaluate the new system, extensive trials were carried out on a powder press TPA300/4HP with a maximum pressing force of 3.000kN, applying a DORST in-house tool with three upper / three lower tool levels and a core rod.



Picture 1: Powder Press TPA300/4HP



Picture 2: Sample of press part

The DORST Netshape® 4.0 – system is a software, which pre-calculates the correct pressing position – on the fly, during the present stroke – by using the parameters described above. This asks for exact measurement of actual forces, elongations, deflections and the actual weight and dimension of the pressed part. The measurement system for the mechanical distortion is an integral element of the powder press itself, while the weight comes from a balance located nearby the press centre, where the robot places the compact instantly after compaction.

In addition, a laser-measuring device for height control is located directly behind the balance. Thus, all important part parameters are measured and the actual values are known.

The obtained data are transferred to the control system DVS/DCS® and processed by the Netshape® 4.0 – system. Since this happens immediately after the cycle, it opens the opportunity to tune the press movements for the next cycle in accordance with the present fill, keeping closer the desired tolerances in all dimensions.

The trials were run with powder mixes of different characteristics, as per following table:

Mix number	Apparent Density	Green Density	Green Density at 600 Mpa
1	Low	High	7,16
2	Low	Low	7,05
3	High	High	7,16
4	High	Low	7,08

Table 1: Powder characteristics (courtesy of Höganäs AB)

### 3.1 Variation in production, due to variation of powder mixes

In order to find out the natural behaviour of the press system, the 1. trial was run without Netshape® 4.0 – system and without weight control. The different mixes were fed each after 50kg. The changes indicated by the vertical blue line in the diagrams below. The variation of the powder parameters are evident: The force was relatively stable, due to the active force control of the top punch, while the weight varied with the powder changes.

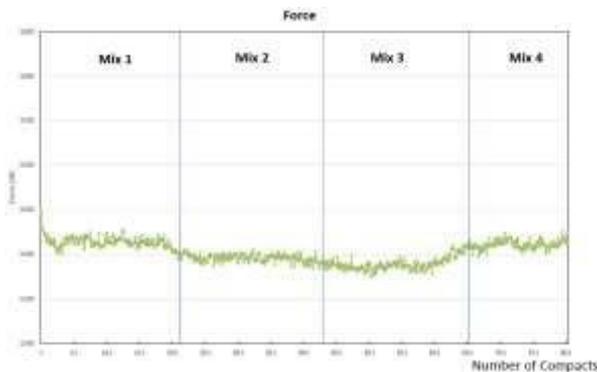


Diagram 1: Force scatter  
(courtesy of Höganäs AB)

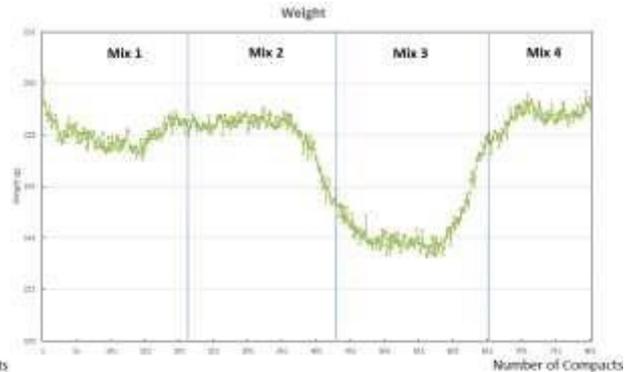


Diagram 2: Weight scatter

### 3.2 Variation of production with weight control and Netshape® 4.0 – system

During the 2. trial, the Netshape® 4.0 – system was enabled together with the weight control. Again, the different mixes were changed each after 50kg in the same sequence as during the 1. trial (vertical blue lines). Now, the variation of the powder was clearly displayed by the force curve, while the weight kept constant. The blue dots indicate activity by the automatic fill height adjustment of the powder press.

The obvious variation in force is a consequence of the difference in compressibility of the four mixes.

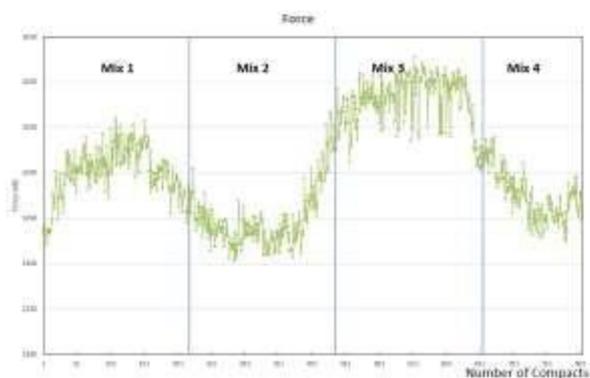


Diagram 3: Force scatter  
(courtesy of Höganäs AB)

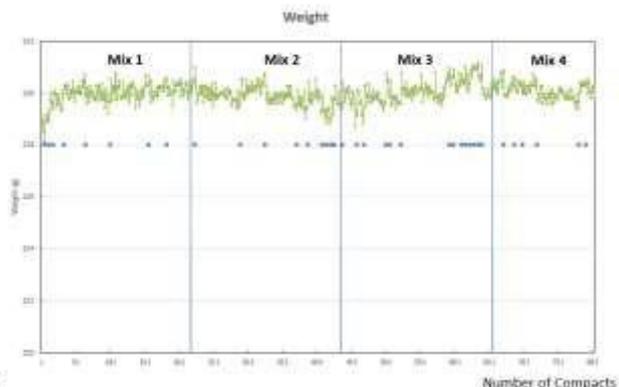


Diagram 4: Weight scatter

This trial proved the capability of the automatic adjustment of the press cycle according to the actual part weight. This is a common technology already used in series-production, however, still with a certain delay between measurement of weight and feedback to the control. Today usually, there are up to 3 – 4 compacts before the weight-result returns from the balance to the control and is processed by the software. Therefore, the re-adjustment of the press cycle and thereby of the compact is possible only within reasonable tolerances.

The placement of a balance either directly in the robot-gripper or nearby the press centre allows the transfer of the weight to the press control before the next stroke. This fast feedback allows the re-adjustment of the fill position of the powder press for the directly following compaction stroke. Therefore, the weight tolerance can be regulated within much tighter tolerances, even under varying conditions. The realized weight scatter is within  $\pm 0,5\%$ , fulfilling highest quality demands.

In order to keep the height, the control-system has to re-adjust additionally the fill- and the press-position according to the powder characteristics. As long as the fill quality is constant, the DORST

Netshape® 4.0 – system assures a constant height of the compact – proven in production trials with the results, presented in following tables.

Weight – 50 parts	Standard cycle	DORST NETSHAPE® 4.0
MAX [g]	230,74	230,88
AVG [g]	230,18	230,28
MIN [g]	229,67	229,92
Range [g]	1,07	0,96
Std.-dev. $\sigma$ [g]	0,2292	0,2147

Table 2: Weight of samples

Height – 50 parts	Standard cycle	DORST NETSHAPE® 4.0
MAX [mm]	15,656	15,623
AVG [mm]	15,643	15,617
MIN [mm]	15,621	15,606
Range [mm]	0,035	0,017
Std.-dev. $\sigma$ [mm]	0,0073	0,0042

Table 3: Height of samples

The above presented results from practice related trials confirm that both, weight and height of the compact can be controlled successfully by adequate systems. The values delivered from such devices can be calculated fast enough in algorithms, to safely control the movements of the next compaction cycle and thus realize tighter tolerances in part dimensions by use of the software Netshape® 4.0 – system.

To accomplish the target of compensation in filling-variation of the die, to assure constant top quality of the compacts produced, even during long production runs with frequent change of powder bags and breaks, due to various reasons, there seem to exist two options:

1. Analyse the relevant powder characteristics, feed them to the press control software and find an algorithm to consider them in the calculation of every press cycle.
2. Identify the actual weight and actual dimensions of the compact, immediately after the pressing and feed these data to the software to re-adjust the press cycle.

@ 1. A solution can be found only in close cooperation between the press maker and the powder producer. DORST Technologies and Höganäs AB made relevant trials to learn about the significant parameters and identifying basic principles that can be applied. On these basic principles, the next steps will be made to pave the way for industrial application of a capable system.

@ 2. The press maker realizes a technology to measure weight and height-dimensions of the compact, as soon it is pressed. To achieve this DORST Technologies refined the existing Netshape® – system by combining it with latest Industry 4.0 technology and advanced software enhanced by new algorithms, therefore now named DORST Netshape® 4.0 – system. The employment of a balance close at the press centre and a laser height measuring system directly applied behind the balance are currently under development at DORST Technologies and first promising results are on the table, as shown in this paper.

#### 4. Conclusion and future Perspective

For the benefit of part production and thereby for the industry of part makers, the target for the equipment producers – like DORST Technologies as a press maker – is, to assure continuous autonomous production of high quality compacts.

This is not exclusively directed to tighter tolerances and thus to higher quality, but in a next step also to prevent the formation of cracks in the green parts.

This will be the desired ideal situation: A powder press-system, immediately responding to any change in the process, self-adjusting to exterior influences.

The final result will be the **AUTONOMOUS POWDER COMPACTING Unit APU**, which will be the future solution in Industry 4.0, using the IoT and the Know How of the machine builder and the user, combining them to the optimum operation of the equipment!

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