

# Study of Powder Pullout Defect during Compaction of Tungsten Carbide- Cobalt Inserts

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**ABSTRACT:** Tungsten carbide-Cobalt (WC-CO) inserts are widely used type of machining tools produced by powder metallurgy. The process of powder metallurgy involves powder mixing, powder compaction, sintering and secondary operations. During the compaction process, various surface defects including crack, powder pullout, burr, pitting, and shrinkage are observed. Powder pullout during 'insert compaction' is an issue that is commonly experienced during 'insert' manufacturing operations. The term 'Powder pullout' refers to a phenomenon that results in the removal of powder from insert surface due to the adherence of powder onto the punch faces. Factors influencing the powder pullout due to powder characteristics, processing parameters and pressing instrumentations, these have been studied and accepted in the literature reviews. Review of literature suggests that, powder pullout is a complex multifaceted phenomenon influenced by number of factors. The main objective of the present study is to identify the root causes for powder pullout and arrive at the solution for the same using DMAIC process of Six Sigma technique. This is hoped to reduce the scrap rate due to powder pullouts, during compaction of inserts.

**KEYWORDS:** Powder pullout, Insert compaction, Tungsten carbide-Cobalt, Powder metallurgy, DMAIC, Six sigma

## I. INTRODUCTION

Powder metallurgy is the manufacturing science of producing solid parts of desired geometry and material from powders. The process of powder metallurgy involves powder mixing, powder compaction, sintering and secondary operations. Among many other manufacturing processes, powder metallurgy is preferred, because it can produce near net shape products requiring less or no secondary machining other than increasing mass production rate comparable with those of conventionally produced products. Inserts are cutting tool tips produced by powder metallurgy and their main use is to cut metal materials into the desired geometric shape. The bits are replaceable and can be used as turning inserts, milling inserts, and drilling inserts. The selection of cutting tool material and grade is an important factor to consider when planning a successful metal cutting operation. Common materials for the cutting tool inserts include cemented carbide, polycrystalline diamond, and cubic boron nitride. Tungsten carbide-Cobalt (WC-CO) inserts are the most widely used type of machining tools produced by powder metallurgy. During the compaction process, various surface defects including crack, powder pullout, burr, pitting, and shrinkage are observed. Powder pullout during 'insert compaction' is an issue that is commonly experienced during 'insert' manufacturing operations. The term 'Powder pullout' refers to a phenomenon that results in the removal of powder from insert surface due to the adherence of powder onto the punch faces 'Powder pullout' refers to a phenomenon that results in the removal of powder from insert surface due to the adherence of powder onto the punch faces. During the compaction of inserts various surface defects are observed. Some of commonly observed defects during the compaction of inserts are as follows.

- Pits – Pits are also known as pinholes. These are the randomly occurring voids in the materials, commonly caused by powder contamination.
- Cracks – Long narrow voids or separations in the material.
- Flash – Protruding material defect caused by clearance between die and punch
- Powder pullout: Surface material loss due to adhesion of powder to the punch
- Dirty Punch Mark: Surface material indentation due to dirt on punch

- Chips – Broken or damaged due to handling.
- Mixed Grade – Results from contamination of powder with another grade, characterized by spots or areas of other color than bulk of surface.

## II. RELATED WORK

James V Thomas has reported on “Evaluation and study on the adhesion of powder onto punch faces during tablet compaction”. Sticking is a multi-faceted phenomenon because there are numerous factors that can simultaneously contribute to the issue. Sticking has been shown to be affected by several factors including compression speed, compression force, and lubricant concentration, powder processing conditions, punch surface chemistry, punch surface roughness, punch geometry, moisture and temperature. Currently, there is truly a lack of the fundamental understanding of the mechanisms that lead to sticking. S A Rolland, D T Gethin, R W Lewis and J H Tweed have reported “Failure risk in powder-compacted parts”. This study addresses the occurrence of crack-related failure within the powder compaction cycle. Both tensile and shear cracks are considered together with the challenges associated with their detection. “Production handling damages of cemented carbide inserts, A Six-Sigma approach application” is reported by Sotirios Ballas and Peyman Malak Rafat. The purpose of this project was to generate and implement a solution aiming to reduce the deficiencies occurrence in the manufacturing process of cemented carbide inserts. “Reducing the defects rate by the implementation of six sigma technique at led-bulbs manufacturing company” is reported by Rajana Kishore, Shaikh Saidu, V. Harikiran and S. Ganesh. This study presents a quality improvement applied at LED-bulbs manufacturing company based on six sigma techniques. One of the Six Sigma techniques, DMAIC (Define, Measure, Analyze, Improve, and Control) & various tools are utilized to improve the productivity of the company

## III. METHODOLOGY

Six Sigma is a disciplined, statistical-based, data-driven approach and continuous improvement methodology for eliminating defects in a product, process or service. Many companies around the world have adopted Six Sigma methodology as a way of doing business. Sigma represents the population standard deviation, which is a measure of the variation in a data set collected about the process. If a defect is defined by specification limits separating well from bad outcomes of a process, then a six sigma process has a process mean (average) that is six standard deviations from the nearest specification limit. This provides enough buffers between the process natural variation and the specification limits. Six Sigma can also be thought of as a measure of process performance, with Six Sigma being the goal, based on the defects per million. **DMAIC** is a data-driven Six Sigma methodology for improving existing products and processes. The **DMAIC** process should be used when an existing product or process can be improved to meet or exceed the customer’s requirements. **DMAIC** methodology consists of five phases: D – Define, M – Measure, A – Analyze, I – Improve, C – Control

- Define – Define the project targets and customer deliverables.
- Measure – Measure the process to determine the current process performance
- Analyse – Find out the root causes of the defects.
- Improve – Improve the process by eliminating defects.
- Control – Control the future performance.

## IV. EXPERIMENTAL RESULTS

### Define Phase

The first stage of the Six Sigma and DMAIC’s methodology is “define”. This stage aims at defining the project background, identifying the voice of the customer (i.e. customer requirements) and process flow of the project. In Insert Production plant, Powder pullout is observed during pressing of inserts. The term ‘Pullout’ refers to a phenomenon of removal of material from the surface of insert due to adherence of materials onto the punch faces as shown in fig 1



Fig1 Powder Pullout



The different types of defects observed and their percentage of occurrences during the period of 6 months of observation in insert manufacturing plant is as shown in fig 2

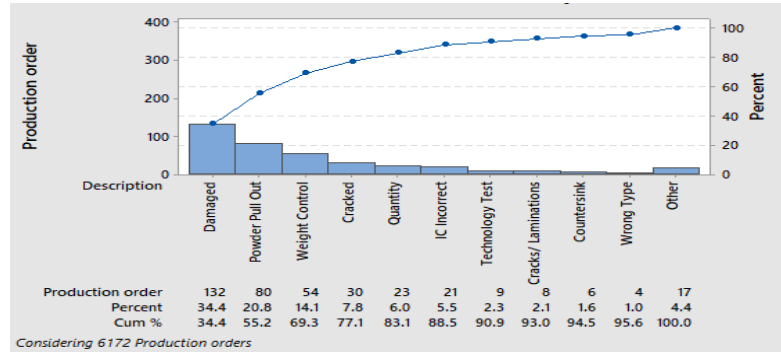


Fig 2. Pareto graph of defects observed during insert compaction

The SIPOC (Supplier, Input, Process, Output, and Customer) of the insert manufacturing is identified and the High level process map is defined as shown in table.

| Supplier | Input                | Process              | Output | Customer                 |
|----------|----------------------|----------------------|--------|--------------------------|
| PU-1     | Powder               | Compaction of Insert | Insert | Green Compact Inspection |
| PU-4     | Press tool           |                      |        |                          |
| PU-5     | Operator             |                      |        |                          |
| PU-5     | Pressing environment |                      |        |                          |

**Measure Phase**

The “measure” phase of the DMAIC process is a problem solving methodology consists of establishing reliable measurement system. In this project the “measure” phase deals the definition and selection of effective measurement method in order to clarify the major defects which needed to be reduced. Also, a data collection plan was adopted for the data to be gathered efficiently. One of the measurements defined was simply number of defects per type. After defining the total number of defects, the DPMO and Sigma level of the insert manufacturing process were calculated.

Project Y Capability and Current Sigma Level

Number of Defects: 82

Units checked: 6172

Number of opportunities: 1

$$DPMO = \frac{Defects \times 10^6}{Units\ checked \times Opportunity}$$

$$= \frac{82 \times 10^6}{6172 \times 1} = 13285$$

From DPMO and Sigma level conversion table, current Sigma level is found to be 3.72.

Hence the main objective is to reduce the defect rate, so that sigma level will increase.

**Analyse Phase**

This phase in the DMAIC process involves the analysis of the system, in order to identify ways to minimize the gap between the current performance and the desired goal. In this case, manufacturing process that produces the cutting tool insert is to be analysed. To do this, an analysis and investigation of data collected is done to determine and understand the root cause of the defect. A detailed process flow of insert compaction is done to identify inputs, outputs and sequence of the process. Once the inputs, outputs and sequence of the process were understood an analysis was carried out to identify the root cause(s) of the defects.. The cause and effect diagram for powder pullout in inserts is as shown in figure

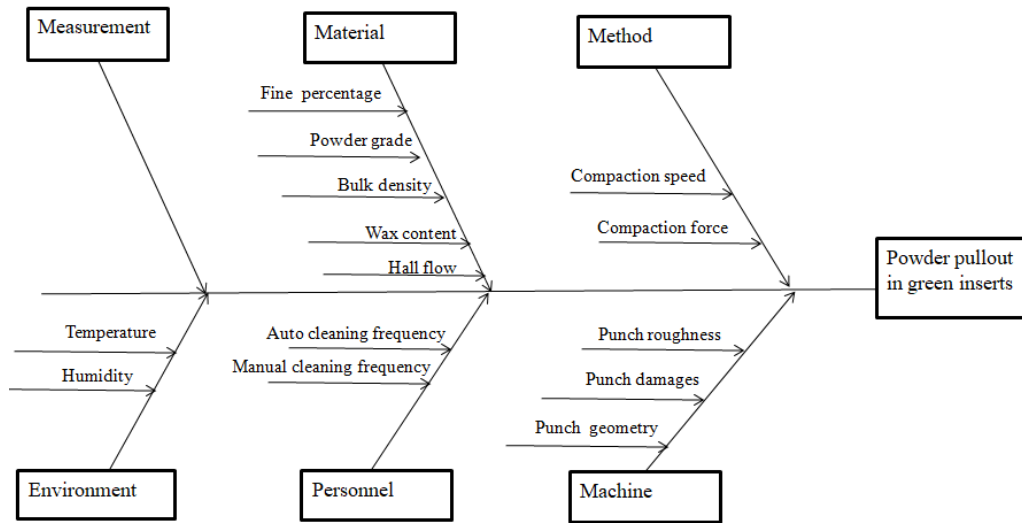


Fig 3 Cause and effect diagram for powder pullout

Based on these possible causes, Cause validation plan is done to identify the actual causes for the powder pullout.

### Improve and Control phase

After determining the root causes, “improve” phase of DMAIC process aims at identifying solutions to reduce and solve them. Based on analysis of various causes, solution is to be proposed. Proposed solutions are as follows;

- Punch surfaces are to be well polished, so that roughness is to be less than 1 microns.
- After compaction of every 10,000 inserts, punches needs to be sent for polishing and rework.
- Temperature and relative humidity is to be maintained within the recommended zone.
- Percentage of fines (smaller granules) in powder is to be less than 30 grams.
- Wax is added during powder manufacturing as a binder. Higher the Percentage of wax, occurrence of powder pullout is more.
- Cleaning frequencies is to be set as per complexities of punch geometries. For complex geometries of punch, cleaning frequencies needs to be set lower.

The final step before project closure was to assure that the improvements and results achieved within the six sigma project would sustain.

Design of experiment is planned based on the proposed solution and it is observed that pullout occurrence in inserts are reduced and Sigma level is increased to 4.2.

## V. CONCLUSION

The purpose of this study was to generate and implement a solution aiming to reduce the defect occurrence in the manufacturing process of tungsten carbide-cobalt inserts. The main focus has been the identification of potential root causes responsible for the Powder pullout defect during compaction of inserts. A six sigma methodology has been used for the study. From the study, it is found that powder pullout is a multifaceted phenomenon influenced by number of factors simultaneously. Powder characteristics, processing parameters and pressing instrumentations have been studied and it is found that roughness of punches, damages in punches, higher fine percentage and wax percentage in powder, temperature and humidity at the time of powder storage and insert compaction, and cleaning frequencies are the main factors influencing powder pullout defect in inserts.

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