Manufacturing of Metal Matrix Composites: Optimization of the Powder Metallurgy Process

Bassam Jihad (CHE) Refaat Ali (MCE) Ali Babar (IE) Tanveer Chowdhury (IE)

Situation

Metal Matrix Composites (MMC) is a material made up of combination of metal and ceramics which combines both properties of parent materials. MMC have some significant advantages, such as providing better mechanical strength and resistance to corrosion [1]. They can be produced by different methods ways, but our focus will be on Powder Metallurgy (PM).

Problems

- The production of MMC is time consuming conventional ball mill.
- The manufacturing of MMC results in overheating of the product which may cause deformation.
- Perfect surface finish is unachievable
- High energy consumption in the conventional ball mill

PM Process

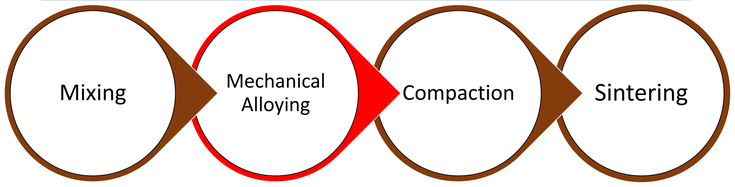

Figure 1: PM process steps

Powder Metallurgy: it is the production and working of metals as fine powders which can be pressed and sintered to form objects.[2]

Mechanical Alloying: is a solid state powder processing technique involving repeated welding, fracturing and re-welding of particles in a high-energy ball mill.

Why is it important?
- Reduces the need for subsequent machining.
- Wastes very little material.
- Good dimensional control.[2]

Solution

High Energy Ball Mill Concept

- Size reduction on a nanometer scale & Mechanical Alloying require a very high energy input.
- Materials that cannot be alloyed by **fusion**, can be carried in ball mills which provide high energy input through **impact & friction**.[3]

By optimizing these components we can achieve the desired product phases and/or microstructure:
- Type of Mill
- Milling rotational speed
- Temperature of milling. [5]

Basic Principle:
- On top of rotating discs, bowls or jars filled with powder mixture are placed.
- A centrifugal force is created by rotating a jar around its own axis and the rotating disc in the opposite direction.
- The powder mixture is fractured & cold welded under high energy impact.[4]

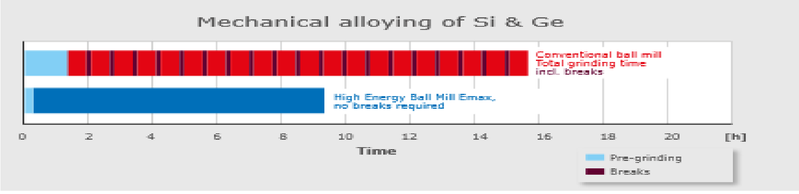

Figure 2: Comparison between high energy and conventional ball mill [3].

- For effective cooling temperature system is an essential requirement

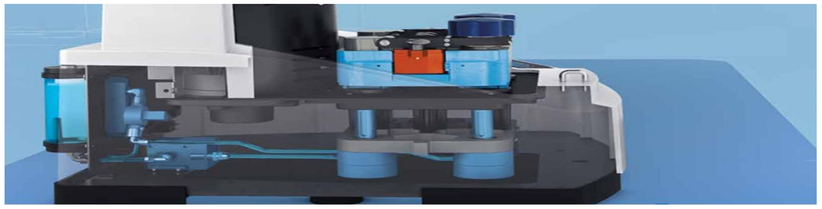

Figure 3: Cooling system [3]

Evaluation

- Particle size vs relative frequency– at a certain particle size the relative frequency of collisions is higher, due to faster RPM. Hence, it reduces the time required to produce the powder.

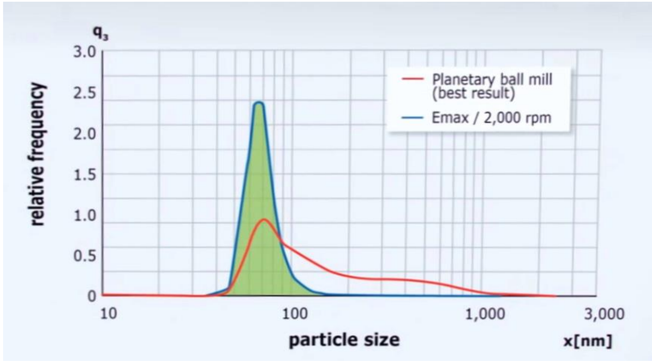

Table 1: Relative frequency vs Particle size [3]

- Net grinding time – compared to the convectional planetary ball mill the required particle size is achieved in less time.

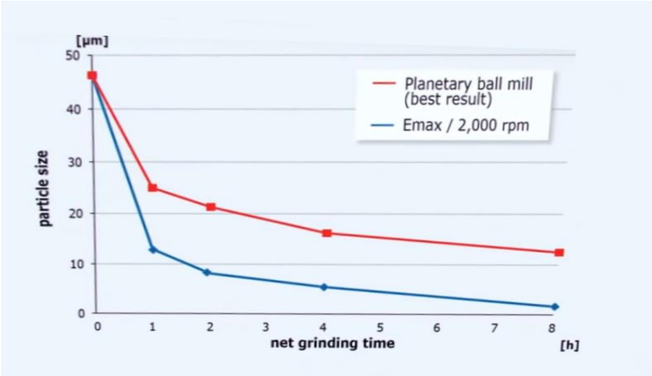

Table 2: Net grinding time vs Particle size [3]

- Cost – initial cost is high due to the increased energy input and cooling system, but on the long run, the shorter operation time compensates for the high initial cost. [3]

References

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