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Research Paper

HOT FORGING LUBRICANTS

Ujjwal Kumar[1]*, Ajay Kumar Mishra[1] and Rajkumar Ohdar[1]

*Corresponding Author: Ujjwal Kumar, ✉ kashyapujjwal6@gmail.com

Importance of lubrication In a Hot Forging process and die lubrication is the key for quality and productivity. Lubrication, however, is not an easy job and is very dependent on the right selection of parameters such as: Lubricant and application types, team supervision and operator experience, even when fully automated systems are employed. A lubricant for forging dies is a chemical compound that has a formulation that makes possible the forging process to be carried out within the limits and parameters considered by the forging industry. An attempt here has been made to elaborate and discuss the different aspects of the topic.

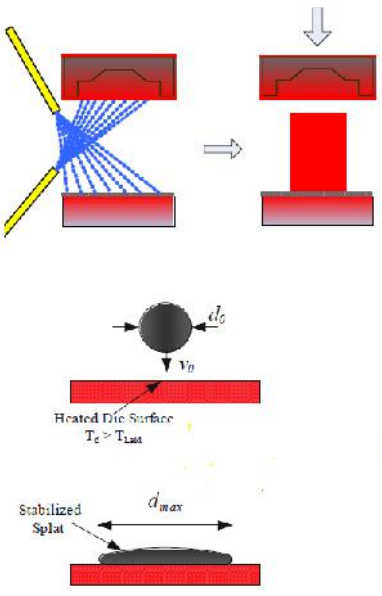
Keywords: Die, Forging

INTRODUCTION

In the hot forging processes, the dies are lubricated and cooled by spraying dilute water based lubricants on the heated die surfaces. This spray is produced by atomizing lubricants into small droplets using spray devices with pressurized air Figure below.

Figure 1, Lubrication spray process (top) modelled as the spread of a single droplet (bottom). The physical parameters are d_o, d and d_{max} (the initial, evolving and maximum diameters of the drop respectively); V_o the initial droplet velocity.

Figure 1: Overview of Lubrication



Source: Yang and Shivpuri (2006)

LUBRICANTS

A lubricant for forging dies is a chemical compound that has a formulation that makes

[1] Department of Forge Technology, National Institute of Foundry and Forge Technology, Ranchi 834003, Jharkhand, India.

possible the forging process to be carried out within the limits and parameters considered by the forging industry.

Importance of lubrication in a Hot Forging process is the key for quality and productivity. Lubrication, however, is not an easy job and is very dependent on the right selection of parameters such as: Lubricant and application types. Team supervision and operator experience, even when fully automated systems are employed.

CHARACTERISTICS OF IDEAL LUBRICANT

- Reduce the sliding friction between dies and work piece (Load and energy requirement will be reduced).
- Works as a parting agent between die and work piece. (Prevents sticking).
- Works as an insulator.
- It should develop a balanced gas pressure (Especially in hammer forging with impression (this is called Dieseling effect)).
- Should be Non-Abrasive and Non-Corrosive.
- Shouldn't create smoke (Pollution free).
- Availability with reasonable cost.

The lubricant is often a fine suspension of fine graphite particles in water, with surfactants (that lower the surface tension) and binders added to aid in the spreading and formation of adherent lubricant films. As the phenomena of spraying, spreading and film formation are poorly understood, the lubricant is often applied in large quantities resulting in excessive cooling of the surface, and excess graphite in the die cavities and the atmosphere. Consequently, understanding the ideal spraying conditions for lubricant spread and film formation has become critical to both the forging and lubrication industrial communities.

Based on co-efficient of friction lubricants can be divided in two categories:

1. With low co-efficient of friction (In practice).
2. With high co-efficient of friction.

WHY DO WE USE LUBRICATION

- Reduction of forging loads
- Resistance to sticking-release properties
- Cooling
- Improved die life
- Assistance to metal flow
- Protection of dies and tools (coatings)
- Reduced reject
- Reduced friction
- Reduced scale-die and forging

TYPES OF FORGING LUBRICANTS

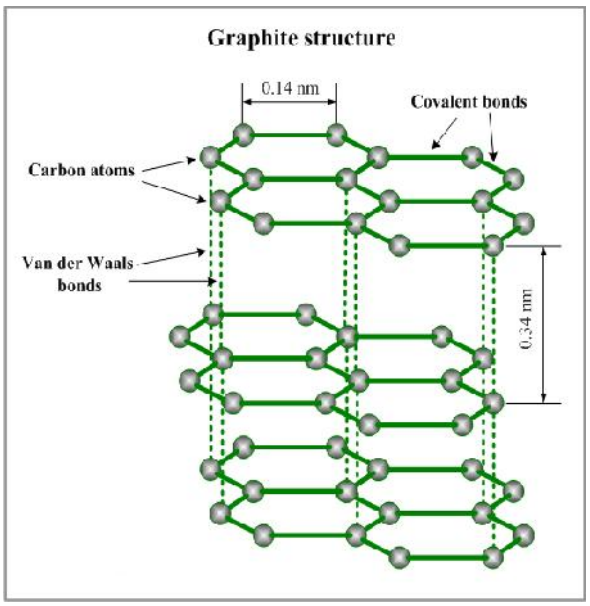
Graphite (A1-Water Based A2-Oil Based): It is a safe, non toxic, lamellar solid offering excellent friction reducing properties. Careful selection of particle size and type allows use over an extremely wide range of temperatures.

Non-Graphite (B)

Types of Graphite

It consists of soluble salts and polymers which perform under less severe conditions, requiring a lower degree of lubrication.

Figure 2: Structure of Graphite



Source: http://www.substech.com/dokuwiki/lib/exe/detail.php?id=graphite&cache=cache&media=graphite_structure.png&DokuWiki=c9040bae6ad67ef164d3f1e1c5e2a95b

Oils(C): Traditional carrier for solid lubricants offering good wetting and flow characteristic, used on their own, oils become subjected to film breakdown under condition of temperature and pressure.

Molybdenum Disulphide (D): It is capable of performing under extreme load and relatively low 3 temperatures, up to 400 °C.

Boron Nitride (E): It is relatively expensive material gaining acceptance and new applications.

Wax (F): Traditional paraffin/mineral wax used on light alloys. These along with modern polymers are more often used as additives to improve performance of lubricants.

Grease (G): It is a traditional product often containing graphite. Used similar to oils, but convenient for application in low volume and lower temperature application.

Glass (H): Used with superalloys on billet and preforms offering protection from furnace atmosphere and forging lubrication in the molten state, composition choice allows extension of temperature working range.

Nickel (K): A limited specialized plating process for high temperature precision forging of steel and nickel based alloys where glass is unsuitable.

Some other categorization:

- Synthetic compounds based on organic salts.
- Saw dust (for deep impression).
- Al-Graphite in mineral oil.
- Mg-alloy-Graphite in mineral oil.
- Cu-Graphite in aq. Solution.
- Ti, Ni, W-Glass in slurry/powder.

Graphite

- Graphite is one a grey crystalline allotropic form of carbon with its origin as natural or artificial.

Graphite an allotrope of carbon considered the highest grade of coal; just above anthracite alternatively called meta-anthracite is best known for Geometry of the particles, Particle size, Degree of purity for being used in lubrication system as hot forging lubricants.

Graphite can be obtained naturally or artificially.

Differences which lie between the natural graphite and the synthetic or artificial graphite are:

- Differences are more in the productive process rather than in the structure, Properties are almost identical.

- Natural Graphite: mineral extraction.
- Artificial Graphite: Produced from petroleum coke.
- Only natural or artificial graphite's of hexagonal and crystalline structure properties are appropriate amorphous graphite's do not possess adequate lubricating.

Very small particles of graphite are not always necessary in a given formulation. The combination of particle size and contained carbon contain is what really makes the difference to be used as lubricants.

LUBRICANT CARRIERS

Carriers are the means of transporting the lubricant agent to the die/tool. The condition such as die temperature, die material, forging configuration, will dictate which carrier is most suited. Water and Oil are the main carries employed and to a lesser degree solvents.

Water

Most commonly used, must be spray applied to dies and offers a very safe and clean working environment. Water is added to concentrated lubricant dispersions to make this type of product very economic in use.

Oil

More traditional carrier and agent used on higher temperature tooling or die areas which are rather inaccessible. Vegetable oils and synthetic oils are being used to replace mineral oils which can offer health and safety drawbacks.

Oil-based products are often used as supplied. Excessive quantities of oil that are not burnt off prior to forging will cause explosion/dieseling in die pockets and can resulting die and forging damage.

Solvents

Quick during alcohols are used for precoatings of tooling, billets and preforms requiring lubricating or protective coatings.

VARIABLES OF THE FORGING LUBRICANTS AND THEIR IMPACT

Parameters Related to Work Piece / Die

- Material properties of work piece (Flow stress).
- Die geometry.
- Surface finish of w/p.
- Scale.

Parameters Related to Lubricants

- Composition of lubricants.
- Viscosity of lubricants.
- Amount of lubricants.

Process Parameter

- Pressure of deformation.
- Die velocity.
- Heat generated due to deformation.
- Sliding length.

Some of the variables which impact the adherence and other properties between the lubricants drops mainly are:

- Degree of dilution of the concentrate
- Density of the lubricant mist
- Temperature of the die
- Pressure of the application of the lubricant over the die.

MAIN INGREDIENTS OF A FORGING LUBRICANT

A major ingredient used in forging lubricants mainly consists of:

- Demineralized water
- Crystalline graphite (natural or synthetic)
- Binding agents
- Stabilizers
- Thickeners
- Bacteriological inhibitors

METHODS OF APPLICATION

Swabs, Mops, Brushes and Cloths

Not always uniform with regard to thickness and distribution and can be uneconomical in use of lubricants. Can sometimes be an advantage where lubricants are required on a particular part of the die which is difficult to lubricate by sprays.

Sprays

Hand Held Spray Gun: It can be used in all forging applications with a variety of lubricants.

Fixed Spray System: It is associated mainly to high volume manual and automatic forging.

Reciprocating Spraying Machine: Generally it is used for medium to large impressions of complex configuration and for volume application applied with programmed spray arms.

Pumping/Flooding: It is used for special extrusion processes or extremely high volume application of water or oil based lubricants.

Pre-Coating: Generally used for protective or glaze coatings as batch processes like electrostatic spraying, dipping or plating.

Important factors governing spray deposition can be categorized into three groups: those related to the hot die surface, those related to the lubricant properties, and those related to the spray characteristics. The factors related to die surface include the initial surface temperature, its roughness, its geometry (cavity design) and surface treatments (such as diffusion treatments or coatings). Important lubricant properties include surface tension and viscosity. Lastly, the spray characteristics involve droplet size, droplet velocity, dilution ratio (or solid content) and, spray cone angle and nozzle height. Composition of the lubricant and the selection of the spray parameters are often determined by the lubrication and cooling needs of the intended application.

CRITERIA FOR SELECTION OF LUBRICANTS

Selection of the most appropriate lubricant for the individual forging process is most important. Criteria needed to be considered are as follows:

- Offer no safety hazards
- Material being forged
- Forging process and type of a production plant
- Must aid and assist die life
- Operate under a minimum of supervision/ easy to manage

Die lubrication and formulations are extremely widespread and particularly the graphite ones. It is possible to design features to suit a specific forging application by the type of raw material used and method of the

lubricants manufacture. It is therefore appropriate to discuss such detail of selection with die lubricant supplier.

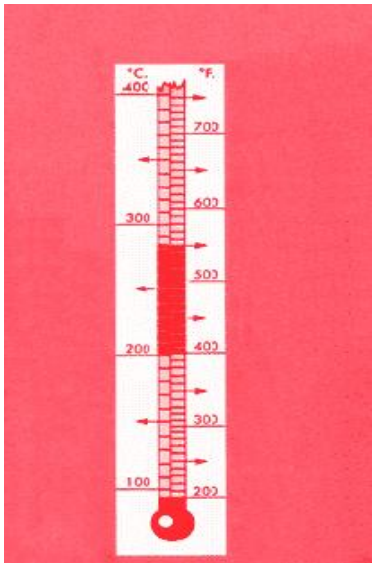
ROLE OF FORGING LUBRICANT TO PROMOTE EXTENDED DIE LIFE

- In first place forming a bonded film over the working die surface
- Secondly imparting to the die surface a reduced friction coefficient able to promote a smooth metal flow
- In third place imparting cooling properties
- In fourth place not generating build ups on the die surface

WORKING TEMPERATURE OF THE FORGING LUBRICANT

To perform within accepted parameters the forging lubricant has to function at temperatures between 200 and 300 grades centigrade's.

Figure 3: Ideal Temperatures for Application of Lubricants



SOME IMPORTANT FACTORS AND THEIR EFFECTS ON DIFFERENT ASPECTS

Affecting Removal of Heat from the Dies

- Density of the lubricant.
- Pressure of the lubricant deposition over the dies.

Affect of Friction Coefficient

- Adherence of the lubricant film to the dies.
- Type and characteristic of the lubricant used.

Influences the Die Temperature

- Mass and contact time of the billet over the dies.

FACTOR NOT ALWAYS TAKEN CARE OF IN THE LUBRICATION

Some of the factors which are not taken care of most of the times in forging correlated to lubricants, which should be taken care of are:

- Quality of the water used in the dilution
- Homogeneity of the diluted lubricant
- Variation control of the solid content prior to
- The application of the lubricant

IMPORTANT TARGET TO ACHIEVE

The most important target to achieve is to keep the total cost of the tooling below the 10% of the total manufacturing cost.

LUBRICATION CONTROLS TO MAKE

In the Concentrate Product

Control of the Manufacturer's Specification

- Type of graphite.
- Particle size.
- Ash content.
- Total solid content and graphite content.
- Viscosity and Ph of the concentrate.

In the Diluted Product

- Check that the solid content chosen is correct and keep it constant during the product usage.
- Check that the diluted product be under continuous agitation in the reservoir tank.

In and During its Application

- Time, angle, size of the lubricating drop, output and distance from the lubricating point to the areas to lubricate.

In the Lubricating Unit (Robots)

- Time of positioning
- Time of blow
- Time of retract
- Time of water cooling
- Output of water
- Time of lubrication
- Output of lubricant

DIE AND BILLET INTERACTION

The Interaction between the die and the billet becomes extremely complicated as:

- Temperature and their control (due to variation in both).
- Transference of heat and its removal (billet cooling and heating and cooling cycles of the die).
- Time of contact billet/die.
- Lubrication.
- Die composition and treatments.

FUTURE PROSPECTIVE AND TECHNOLOGICAL BARRIERS TO OVERCOME

With so many advantages of forging technology in every respect future prospective, advancement in technology and improvement in present techniques becomes a wide field to be discovered. Some of the most important field to be explored in relation to use and application of FORGING LUBRICANTS can be:

- Discovery of new ingredients/formulations that improve lubrication and reduce its incidence in the factors affecting die life.
- Better understanding between the relationship of the lubricating film and the die surface during the forging process.

CONCLUSION

Here in present work we have seen the different aspects of hot forging lubricants from choice of proper lubricant to selection of proper application method, from affect on die life to measures taken proper care of for best results. Quality and free from defects forgings such as surface cracks, internal oxide filling, lack of reduction and use of dies below their maximum potential will only be an achievable target if the culture prevailing within the forging industry recognize the importance of forging lubrication and works towards the

implementation of standardized methods for the evaluation, selection and practical control of the lubricants once in use and also during its experimental trial phase. This culture must be the result of a joint work of the forging industry with the developers and manufacturers of Forging Lubricants.

Finally it does not matter how good the lubricant may be, if not properly applied to the die surface, in the form, angle, pressure, distance and atomization proper for the specific die it will not impart the expected performance.

REFERENCES

1. Gustavo G and Schiuma E (2014), *Die Lubricants for Hot Forging*.
2. Hancox A, Hancox D and Haigh G (1994), "Codes of Best Forging Practice", *Die Lubrication in Hot Forging*, June, British & Midland Forging Ltd., Britain.
3. http://www.substech.com/dokuwiki/lib/exe/detail.php?id=graphite&cache=cache&media=graphite_struc ture.png&DokuWiki=c9040bae6ad67ef164d3f1e1c5e2a95b
4. "Ideal Temperature for Application of Lubricants", http://www.renite.com/forge-lub.htm
5. Manoj Kumar (2013), *Institutes Class Literature*, National Institute of Foundry and Forge Technology, Associate Professor, Department of Forge, Ranchi.
6. Yang L and Shivpuri R (2006), "Spreading Behavior of Water Based Graphite Lubricants on Hot Die Surfaces", *Industrial, Welding and Systems Engineering*, Vol. 55, No. 1, Annals of the CIRP, The Ohio State University, Columbus, Ohio, USA.

APPENDIX 1

METHOD OF APPLYING LUBRICATION							
APPENDIX 1		**SWAB/DIPSTICK MOP BRUSH CLOTH**	**HAND SPRAY**	**FIXED SPRAY SYSTEM**	**RECIPROCATING SPRAY SYSTEM**	**PUMPING OR FLOODING**	**COATING OF SLUG OR PREFORM**
TYPE OF FORGING EQUIPMENT	**DROP HAMMER**	A2, B, C, F AND G	A1, A2, B				H, K
	DOUBLE ACTING HAMMER	A2, B, C	A1, B	A1, B			H, K
	SCREW PRESS	A2, F, G	A1, A2, B	A1, A2, B	A1, A2, B		H, K
	CRANK PRESS	A2, C, F, G	A1, A2, B	A1, A2, B	A1, A2, B	A1, A2	D, H, K
	HYDRAULIC PRESS	A2, G, F	A1, A2, C		A1, A2		D, H, K
	EXTRUSION PRESS	A2, C, G	A1, A2, C	A1, A2, C	A1, A2, C	A1, A2, C	H, K
	HORIZONTAL FORGING MACHINE	A2, C, G	A1, A2, B, C	A1, B			H, K

Source: Hancox et al. (1994)

APPENDIX 2

TYPE OF FORGING																
DIFFICULT PRECISION					**DIFFICULT CONVENTIONAL**				**SIMPLE PRECISION**				**SIMPLE CONVENTIONAL**				**APPENDIX 2**	
SUPER ALLOY	ALUMINIUM	STAINLESS STEEL	STEEL	SUPER ALLOY	ALUMINIUM	STAINLESS STEEL	STEEL	SUPER ALLOY	ALUMINIUM	STAINLESS STEEL	STEEL	SUPER ALLOY	ALUMINIUM	STAINLESS STEEL	STEEL		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A1 WATER BASED GRAPHITE	TYPE OF LUBRICANT
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A2 OIL BASED GRAPHITE	
														✓	✓	B NON-GRAPHITE	
											✓		✓	✓	✓	C OIL	
		✓				✓				✓	✓			✓	✓	D MOLYBDENUM DISULPHIDE	
✓				✓				✓	✓			✓	✓	✓		E BORON NITRIDE	
	✓				✓				✓				✓			F WAX	
✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	G GLASS	
✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	H NICKEL	
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	K GREASE	

Source: Hancox et al. (1994)